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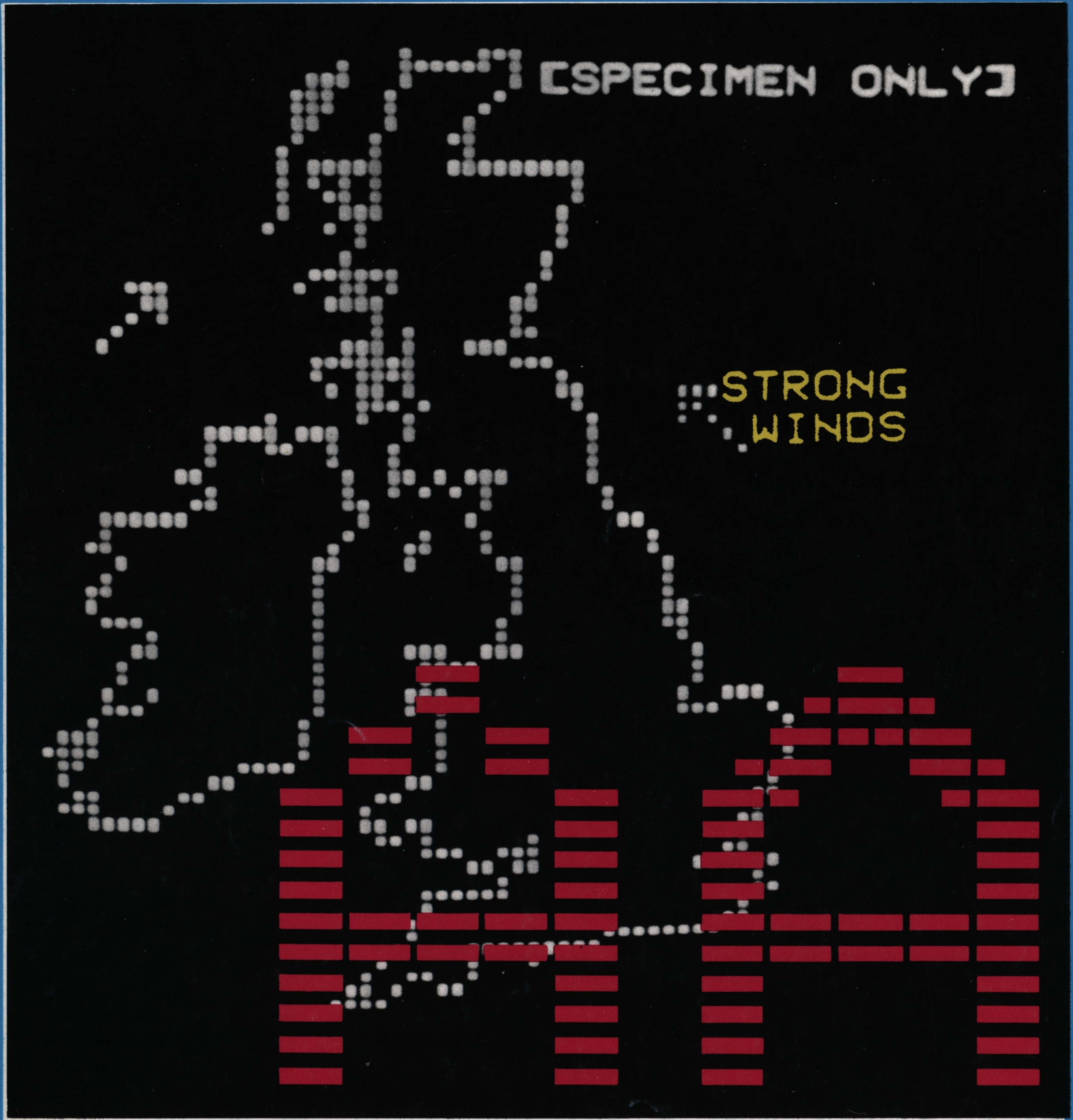

- Character rounding for alphanumeric video display
- A low-cost data display
- Image intensifiers: aids to night vision
- Photocouplers
- High-grade long-life aluminium electrolytic capacitors

Mullard Technical Communications
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Cover Picture:

Weather map, illustrating the graphics capability of teletext alphanumeric display, and two typical characters, one with, and one without, character rounding.

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Character rounding for alphanumeric video display

J.R. Kinghorn
Mullard Central Application Laboratory

UDC 621.397.13 [659.2]

The technique known as 'character rounding' is used to provide characters with improved legibility and appearance on an alphanumeric video display. Effectively, an improved resolution can be obtained without a corresponding increase in the complexity of the character generator. In this article, the principles of the technique are discussed, and a practical character generator circuit (as used in the teletext decoder) is given.

INTRODUCTION

In spite of recent advances in display technology, the cathode ray tube (in one of its various forms) is still the only practical device which can be used to display directly a large amount of alphanumeric information. The visual display unit (VDU) has long been established as a computer peripheral, and recently similar techniques have appeared on the domestic scene with the introduction of teletext tv information services (CEEFAX and ORACLE). A digital memory is used to store information about the various characters required on the screen, and this information is converted into the appropriate video signal by means of a character generator (see Fig.1). This video signal is then supplied to a television cathode ray tube.

An example of the type of display obtained from such a system is shown in Fig.2. This shows a teletext 'page' of information without character rounding. The page is quite legible, but the way in which characters are built up from a series of dots on the screen is quite noticeable and detracts from the general appearance of the display. With character rounding applied (Fig.3), the legibility of the display is improved and its general appearance considerably enhanced. An enlarged portion of the display is shown in Figs.4a and 4b.

All the letters, numbers, and symbols in normal use are made up from a series of lines, and it is this property which is exploited in character rounding. The additional circuitry modifies the video signal from the character generator when a diagonal line is being generated so that a smoother display is obtained. In effect, the dot resolution of the character is doubled in both the horizontal and vertical directions. For example, a character generated on a 7 X 5 dot matrix appears with a 14 X 10 dot resolution.

The operation of the video display system shown in Fig.1 will now be outlined, and then the modifications necessary for character rounding will be discussed. Although this article relates to video display on a cathode ray tube, it should be noted that the technique of character rounding is also applicable to other forms of display device, such as hard-copy printers.

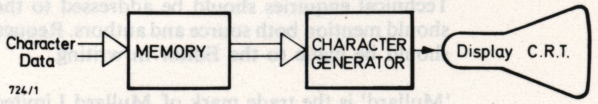
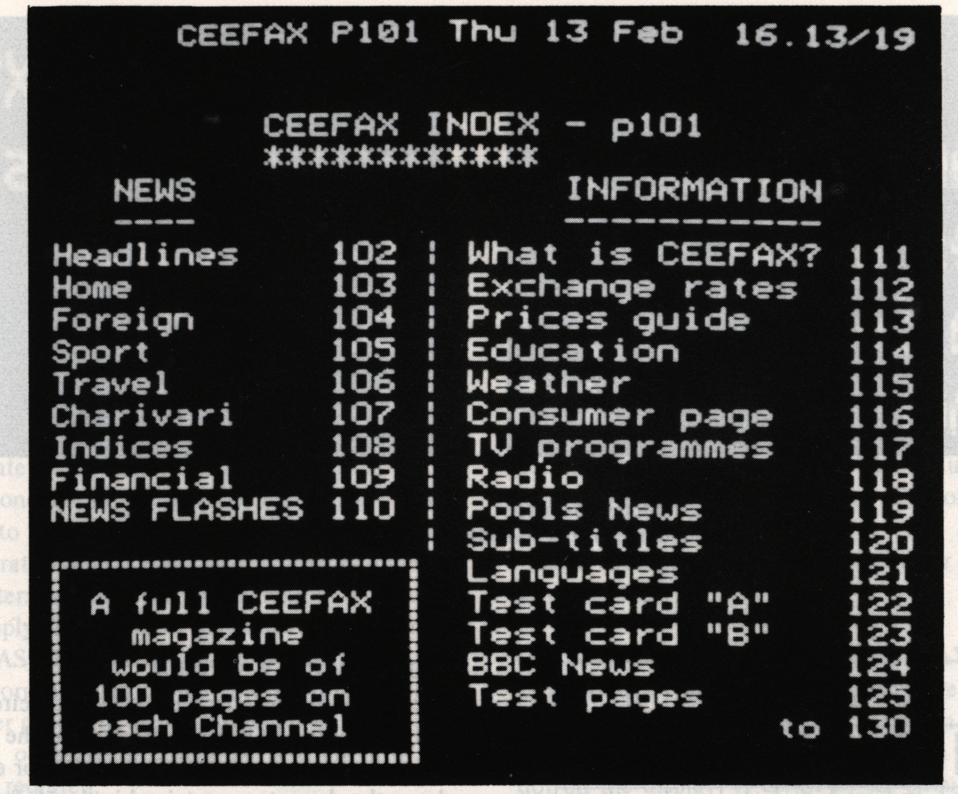


Fig.1 — Simplified block diagram of CRT display system



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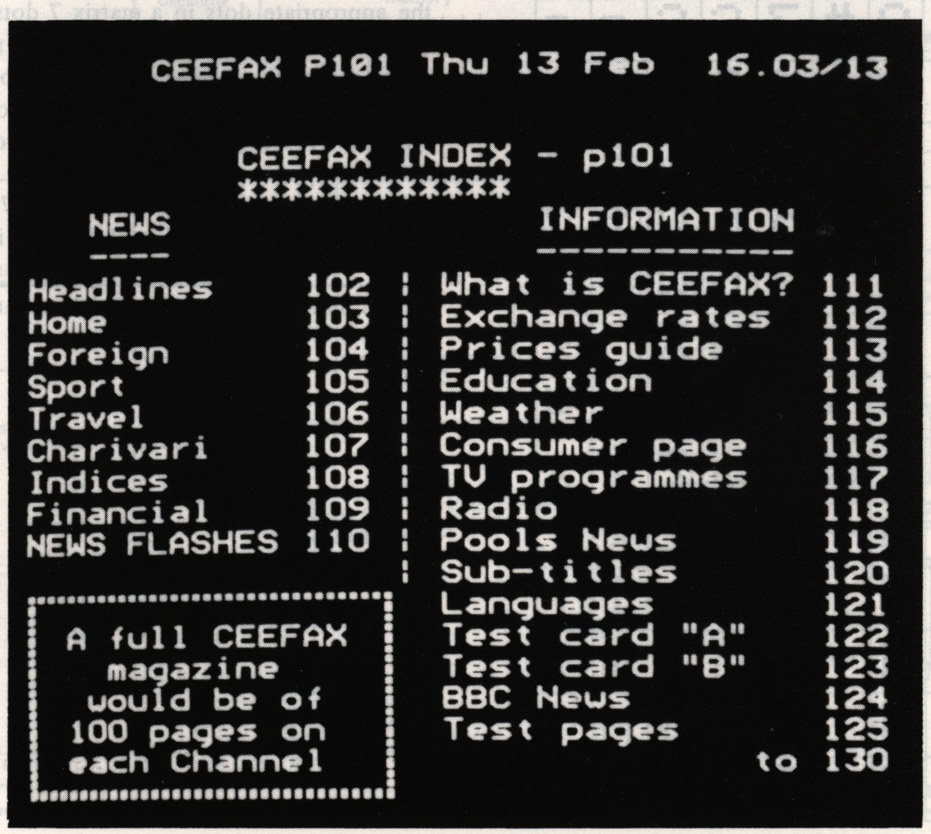
     CEEFAX P101 Thu 13 Feb  16.13/19

        CEEFAX INDEX - p101
        ***********
  NEWS                INFORMATION
  ----                -----------
Headlines      102 | What is CEEFAX? 111
Home           103 | Exchange rates  112
Foreign        104 | Prices guide    113
Sport          105 | Education       114
Travel         106 | Weather         115
Charivari      107 | Consumer page   116
Indices        108 | TV programmes   117
Financial      109 | Radio           118
NEWS FLASHES   110 | Pools News      119
                   | Sub-titles      120
 A full CEEFAX       Languages       121
   magazine          Test card "A"   122
  would be of        Test card "B"   123
  100 pages on       BBC News        124
  each Channel       Test pages      125
                                  to 130
```

Fig.2 — Displayed page of data without character rounding



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     CEEFAX P101 Thu 13 Feb  16.03/13

        CEEFAX INDEX - p101
        ***********
  NEWS                INFORMATION
  ----                -----------
Headlines      102 | What is CEEFAX? 111
Home           103 | Exchange rates  112
Foreign        104 | Prices guide    113
Sport          105 | Education       114
Travel         106 | Weather         115
Charivari      107 | Consumer page   116
Indices        108 | TV programmes   117
Financial      109 | Radio           118
NEWS FLASHES   110 | Pools News      119
                   | Sub-titles      120
 A full CEEFAX       Languages       121
   magazine          Test card "A"   122
  would be of        Test card "B"   123
  100 pages on       BBC News        124
  each Channel       Test pages      125
                                  to 130
```
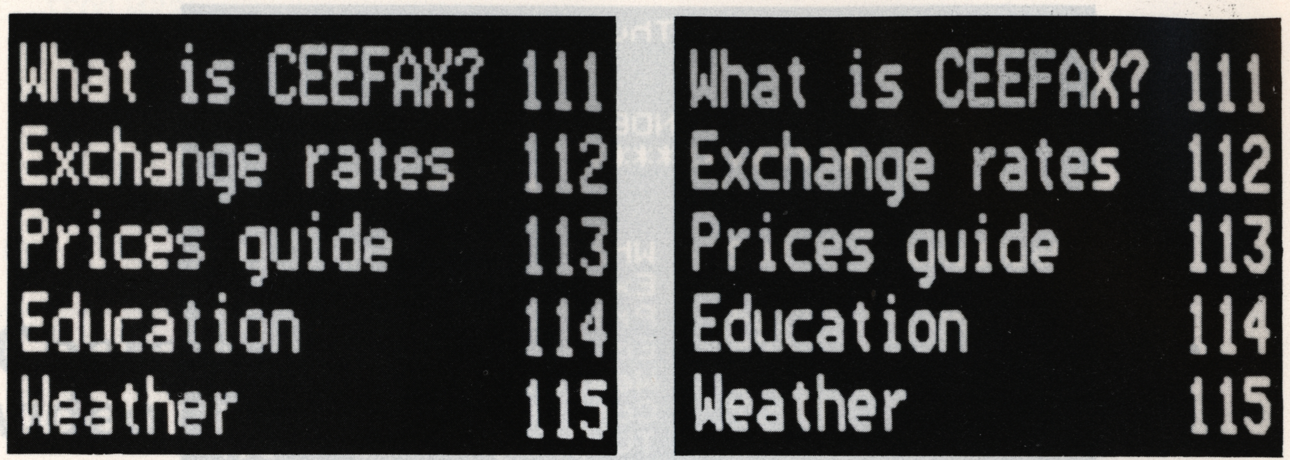

Fig.3 — Displayed page of data with character rounding



What is CEEFAX? 111
Exchange rates 112
Prices guide 113
Education 114
Weather 115

Fig.4 – Typical display characters:
(a) without character rounding (b) with character rounding

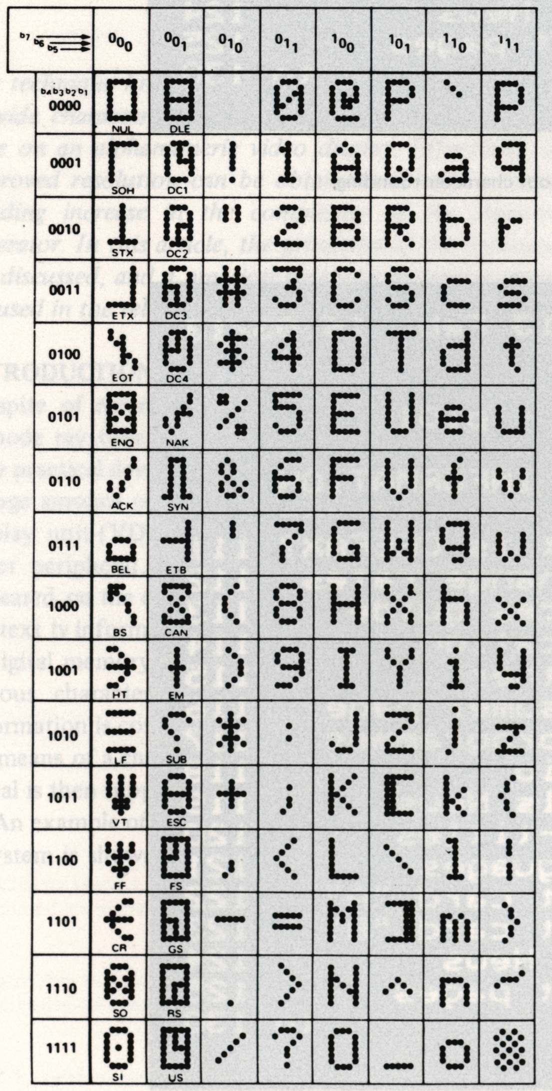

b7 b6 b5
000
001
010
011
100
101
110
111
b4 b3 b2 b1
0000
0001
0010
0011
0100
0101
0110
0111
1000
1001
1010
1011
1100
1101
1110
1111
NUL
DLE
SOH
DC1
STX
DC2
ETX
DC3
EOT
DC4
ENQ
NAK
ACK
SYN
BEL
ETB
BS
CAN
HT
EM
LF
SUB
VT
ESC
FF
FS
CR
GS
SO
RS
SI
US

Fig.5 – Characters contained in FDR146Z2 ROM

VIDEO DISPLAY SYSTEM

The heart of the character generator circuit is a Read Only Memory (ROM) which contains the set of symbols which are required to be displayed. For example, Fig.5 shows the characters contained in the Mullard FDR146Z2 ROM. This device contains 128 symbols, which can be selected by means of a 7-bit ASCII* code applied to the appropriate input pins. Each character is formed from the appropriate dots in a matrix 7 dots high by 5 dots wide. The FDR146Z2 operates on the row scan system, which means that all the dot information in a horizontal row of a character is available simultaneously at the ROM outputs. A second set of inputs, known as the row address inputs, provides the vertical element of the character by determining which of the 7 rows is supplied to the output pins (see Fig.6). The dot information may be loaded into a shift register, and shifted out in serial from to produce a video signal which modulates the CRT brightness during scan.

The display CRT is scanned in the normal way: that is, the beam is made to move across the screen from left to right by a line timebase, and a field timebase scans from top to bottom at a slower rate. Line and field timebase speeds may be chosen to suit the application, but many video display systems use the 625-line television standard. This has a line timebase rate of 64μs (15·625kHz), while the field timebase operates at 20ms (50Hz). Interlaced scanning is used, which means that a complete picture of 625 lines is built up in two fields (40ms), alternate lines being scanned in each field.

Since only one line of video can be scanned at a time, it is necessary to present the character information to the character generator several times over before a complete row of characters is built up. For this reason, a memory is used to supply the character generator. The memory contains the ASCII codes of all the characters on the screen, and is organised to present the appropriate code to the character generator at the correct time.

A new set of characters may be written into the memory when required.

TELETEXT DISPLAY SYSTEM

Consider, for example, the video display system required for teletext. This uses the 625-line tv display mentioned previously. There are 24 rows of 40 characters in the display, 960 characters altogether. Each character is formed on a 7 × 5 dot matrix, with one television line per field used for each row of dots (two tv lines in a complete interlaced picture). A complete row of characters occupies ten tv lines per field, to allow for a space between rows, and so 10 × 24 = 240 tv lines per field are used for data display. In the horizontal direction, each character position is divided into six dot periods, allowing a single dot spacing between characters. The character period is 1μs, and so each dot is $\frac{1}{6}\mu s$ in duration, with the row of 40 characters occupying 40μs of the 64μs line period.

The arrangement of the system for this display is shown in Fig.7.

OPERATION OF THE VIDEO DISPLAY SYSTEM

Clock pulses for the display system are provided by a 6MHz oscillator; this frequency is known as the 'dot rate' since $\frac{1}{6}\mu s$ represents the duration of a single character dot on the display. A divide-by-six circuit then converts

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*ASCII American Standard Code for Information Interchange.

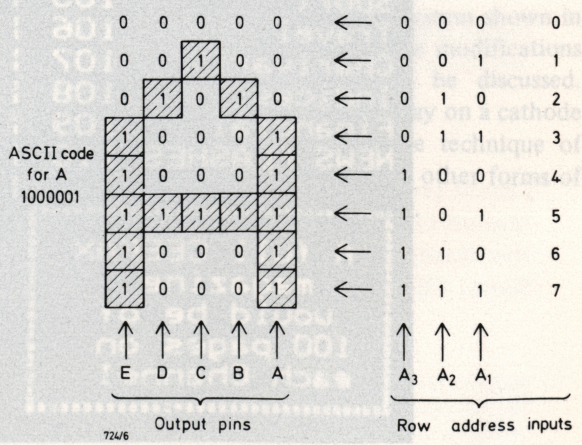

0 0 0 0 0
0 0 1 0 0
0 1 0 1 0
1 0 0 0 1
1 0 0 0 1
1 1 1 1 1
1 0 0 0 1
1 0 0 0 1
0 0 0 0
0 0 1 1
0 1 0 2
0 1 1 3
1 0 0 4
1 0 1 5
1 1 0 6
1 1 1 7
ASCII code for A 1000001
E D C B A
A3 A2 A1
Output pins
Row address inputs
724/6

Fig.6 – ROM organisation

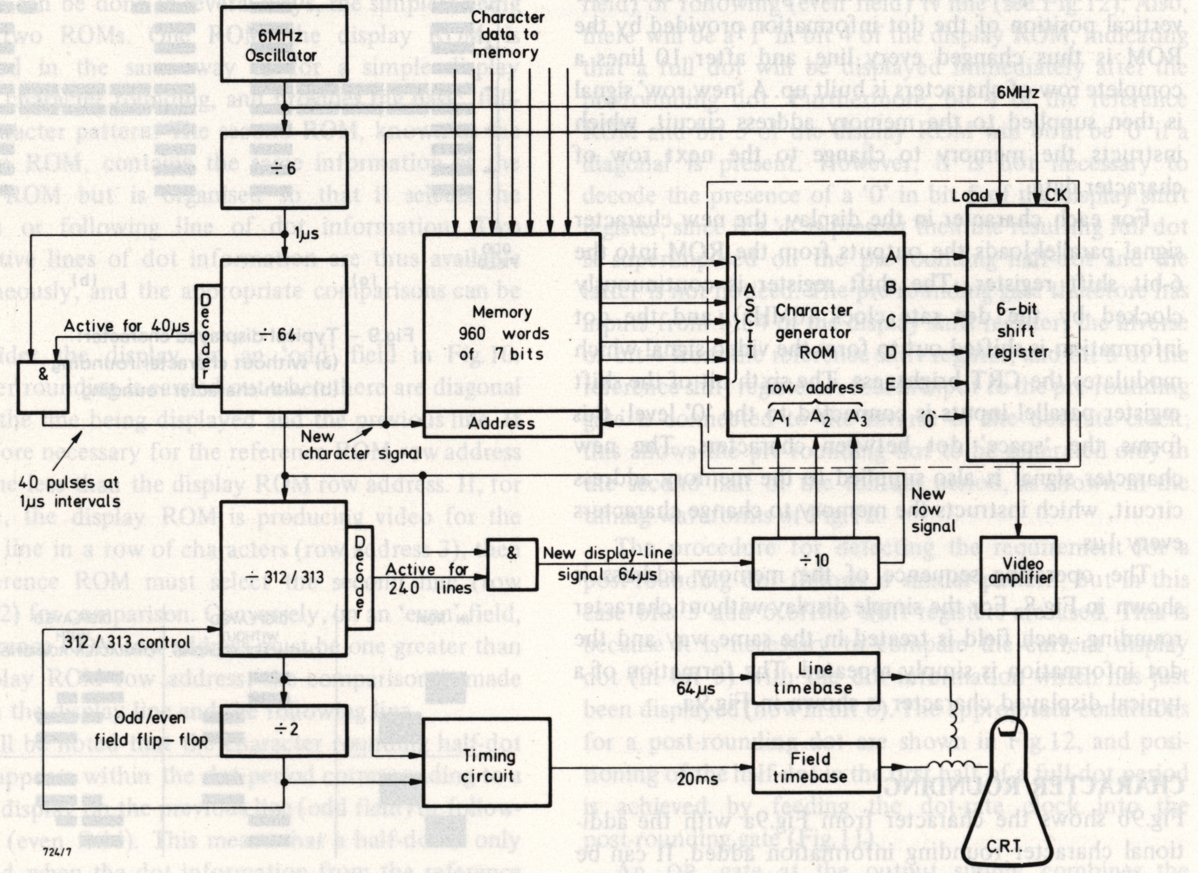

6MHz Oscillator
÷6
1μs
Decoder
÷64
Active for 40μs
&
40 pulses at 1μs intervals
New character signal
Character data to memory
Memory 960 words of 7 bits
Address
÷312/313
Decoder
Active for 240 lines
&
New display-line signal 64μs
312/313 control
Odd/even field flip-flop
÷2
Timing circuit
6MHz
Load
CK
ASCII
Character generator ROM
row address
A1 A2 A3
A
B
C
D
E
'0'
6-bit shift register
New row signal
÷10
Video amplifier
Line timebase
64μs
Field timebase
20ms
C.R.T.
724/7

Fig.7 – Block diagram of video display system

the dot rate into 1μs pulses at character rate. This is further divided by 64 to count through the 64μs of a television line, and a decoder on the 64-counter provides a signal which is active for 40μs out of 64μs. An AND function of this signal and character rate provides a sequence of 40 pulses on every tv line, each pulse coming at the start of each character on the display (new character signal).

The 64μs (line rate) pulses from the divide-by-64 synchronise the line timebase, and are also supplied to a 312/313 counter. This counter operates in conjunction with a divide-by-two flip-flop, to form effectively a 625 counter. The output from the flip-flop is a signal representing odd or even field which controls whether the counter counts by 312 or 313. This signal also goes to a timing circuit, together with the output from the 312/313 counter, which is used to synchronise the field timebase. The timing circuit provides sync pulses either on the line, or halfway through a line (32μs), to form an interlaced display with 312½ scanning lines per field.

A decoder on the 312/313 counter provides a signal active for 240 lines; this is ANDed with line rate to provide a pulse at the end of each tv line during the active display period (new display-line signal). A divide-by-ten unit counts these pulses, its outputs being supplied to the row address inputs on the character generator ROM. The vertical position of the dot information provided by the ROM is thus changed every line, and after 10 lines a complete row of characters is built up. A 'new row' signal is then supplied to the memory address circuit, which instructs the memory to change to the next row of character data.

For each character in the display, the new character signal parallel-loads the outputs from the ROM into the 6-bit shift register. The shift register is continuously clocked by the dot rate clock (6MHz), and the dot information is shifted out to form the video signal which modulates the CRT brightness. The sixth bit of the shift register parallel inputs is connected to the '0' level; this forms the 'space' dot between characters. The new character signal is also supplied to the memory address circuit, which instructs the memory to change characters every 1μs.

The operating sequence of the memory address is shown in Fig.8. For the simple display without character rounding, each field is treated in the same way and the dot information is simply repeated. The formation of a typical displayed character is shown in Fig.9a.

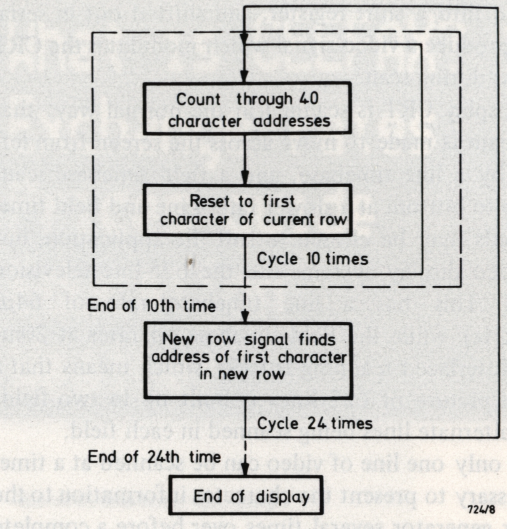

Count through 40 character addresses
Reset to first character of current row
Cycle 10 times
End of 10th time
New row signal finds address of first character in new row
Cycle 24 times
End of 24th time
End of display
724/8

Fig.8 – Memory address sequence

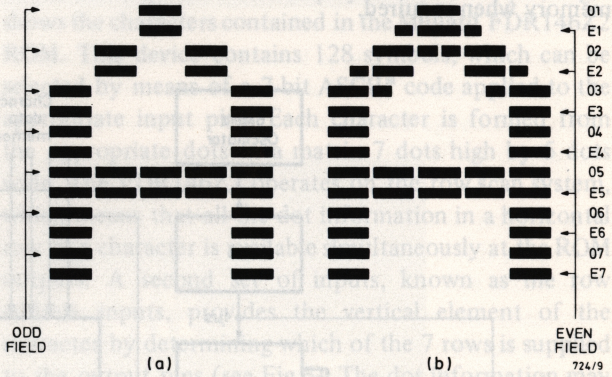


Fig.9 – Typical displayed character:
(a) without character rounding
(b) with character rounding

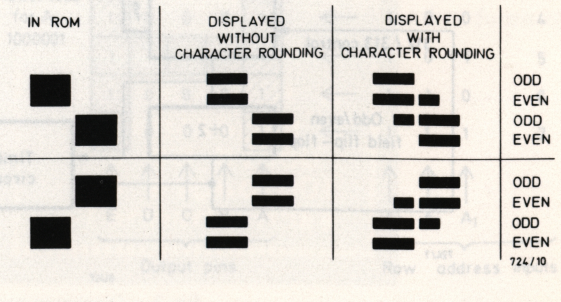

IN ROM
DISPLAYED WITHOUT CHARACTER ROUNDING
DISPLAYED WITH CHARACTER ROUNDING
ODD
EVEN
ODD
EVEN
ODD
EVEN
ODD
EVEN
724/10

Fig.10 – Location of half-dots for character rounding

CHARACTER ROUNDING

Fig.9b shows the character from Fig.9a with the additional character rounding information added. It can be seen that odd and even fields are now treated differently, doubling the resolution in the vertical direction. Half-dots have been added in appropriate places in the display, giving the effect of a doubled horizontal dot resolution also.

Character rounding operates when two dots are found in a diagonal position in any part of the display. As noted previously all normal symbols are made up of lines, and two dots in a diagonal position are considered to be an attempt at a diagonal line. There are two kinds of diagonal line, as shown in Fig.10, and the character rounding circuitry operates to add the half-dots in the positions indicated. This technique is applied to all pairs of lines in sequence to provide full character rounding over the display.

In Fig.10 when the system is on an 'odd' field, the top dot of a diagonal in the ROM is to be displayed unmodified. The bottom dot of a diagonal is to be character rounded, so a half-dot is added either before or after the normal display dot according to the slope of the diagonal. This is done in such a way that the half-dot appears under the top dot of the diagonal. When the system is on an 'even' field, the top dot in the diagonal is character rounded and the bottom dot remains unmodified.

It will be noted that it is necessary to compare the dot information in two consecutive lines in order to detect the presence of a diagonal and provide character rounding. This can be done in several ways, the simplest being to use two ROMs. One ROM, the display ROM, is connected in the same way as for a simple display without character rounding, and provides the basic 'full-dot' character pattern. The second ROM, known as the reference ROM, contains the same information as the display ROM but is organised so that it selects the previous or following line of dot information. Two consecutive lines of dot information are thus available simultaneously, and the appropriate comparisons can be made.

Consider the display on an 'odd' field in Fig.10. Character rounding is carried out when there are diagonal dots in the line being displayed and the previous line. It is therefore necessary for the reference ROM row address to be one less than the display ROM row address. If, for example, the display ROM is producing video for the third tv line in a row of characters (row address 3), then the reference ROM must select the second line (row address 2) for comparison. Conversely, on an 'even' field, the reference ROM row address must be one greater than the display ROM row address; the comparison is made between the display line and the following line.

It will be noted that the character rounding half-dot always appears within the dot period corresponding to a full-dot display on the previous line (odd field) or following line (even field). This means that a half-dot is only displayed when the dot information from the reference ROM is active. The half-dot is positioned within the dot period so that it adjoins a full-dot display from the display ROM. When the half-dot occurs in the second half of a dot period, immediately before a full-dot display, this is known as 'pre-rounding'. Similarly, a half-dot in the first half of a dot period, after a full dot, is known as a 'post-rounding' dot.

A block diagram of a character generator incorporating character rounding is shown in Fig.11. This replaces the section shown within the dotted lines in Fig.7. The display ROM operates in the same way as before, the resulting display video being fed via the OR gate to the CRT. The reference ROM has the same ASCII inputs as the display ROM, but the row address to the reference ROM is supplied via a circuit which adds or subtracts 1 from the incoming row address. An odd/even field input to this circuit selects whether it adds 1 or subtracts 1. An even field is arranged to add 1 (reference ROM one line later than display ROM), and on an odd field 1 is subtracted from the row address (reference ROM one line before display ROM).

The reference ROM outputs are loaded into a 6-bit shift register and the information is clocked out by the dot-rate clock, in a similar manner to the display ROM outputs. When pre-rounding is required, there will be a '1' in bit 5 of the reference shift register, corresponding to a display dot in that position in the previous (odd field) or following (even field) tv line (see Fig.12). Also, there will be a '1' in bit 4 of the display ROM, indicating that a full dot will be displayed immediately after the pre-rounding dot. Furthermore, bit 4 of the reference ROM and bit 5 of the display ROM will both be '0' if a diagonal is present. However, it is not necessary to decode the presence of a '0' in bit 5 of the display shift register, since if a '1' is present then the resulting full dot is superimposed on the pre-rounding half-dot and the latter is not noticed. The pre-rounding gate therefore has inputs from bit 4 of the display shift register, the inverse of bit 4 from the reference shift register, and bit 5 of the reference shift register. A fourth input to the pre-rounding gate is connected to the inverse of the dot-rate clock; this allows the pre-rounding dot to be generated only in the second half of the full-dot period, as shown in the timing waveforms of Fig.12.

The procedure for detecting the requirement for a post-rounding dot follows a similar pattern, but in this case bits 5 and 6 of the shift registers are used. This is because it is necessary to compare the current display dot (in bit 5) with the dot information which has just been displayed (now in bit 6). The appropriate conditions for a post-rounding dot are shown in Fig.12, and positioning of the half-dot in the first half of a full-dot period is achieved by feeding the dot-rate clock into the post-rounding gate (Fig.11).

An OR gate at the output simply combines the normal display video (full dots) with the pre-rounding

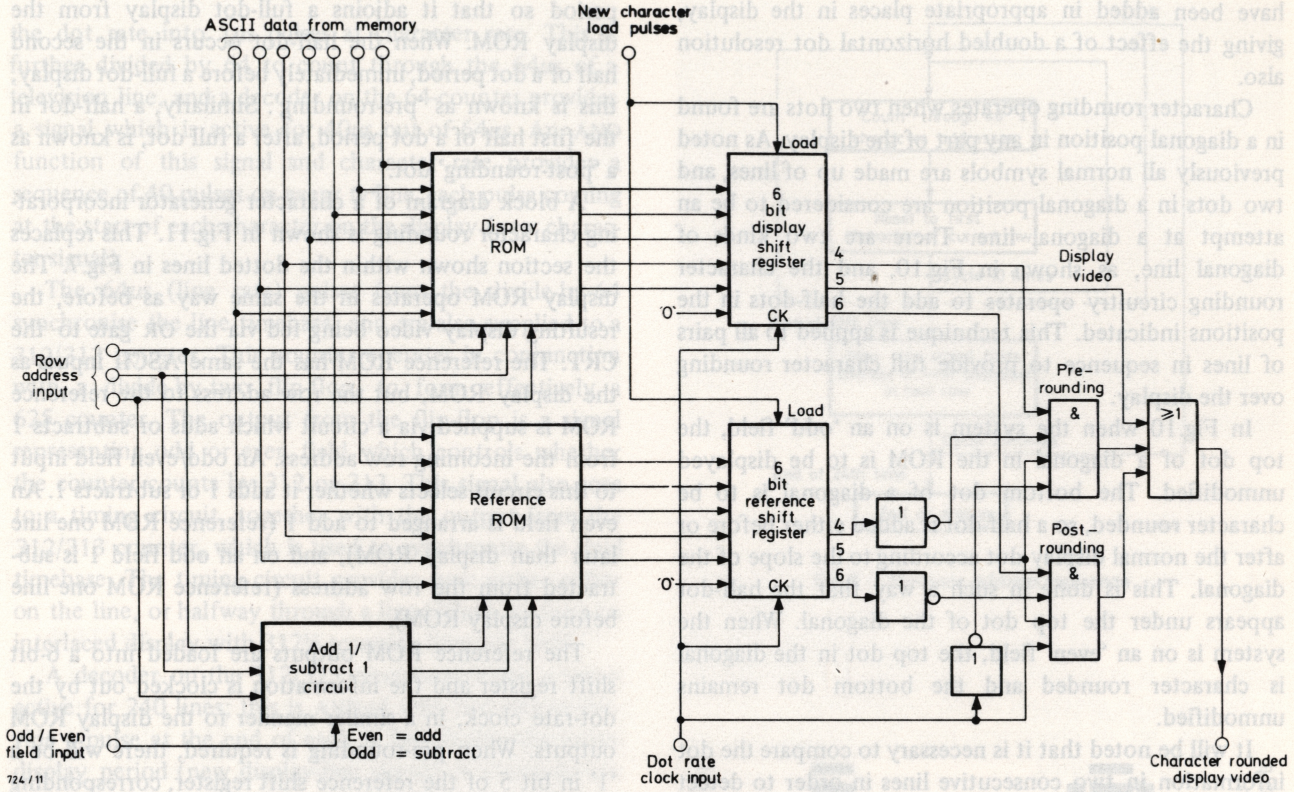


Fig.11 — Character generator with character rounding

and post-rounding information, the resulting output being a completely character-rounded display video signal.

PRACTICAL CHARACTER GENERATOR CIRCUIT

The circuit of a character generator incorporating character rounding is shown in Fig.13. This circuit is used in the prototype teletext decoder system, and is described more fully in Ref.1. Its operation is similar to that of the block diagram of Fig.11, and uses two FDR146Z2 ROMs (Refs.2 and 3). Either 6-bit ASCII coding (upper case only) or 7-bit ASCII (upper and lower case) can be accommodated; the link A selects between the two options. A complication exists when displaying the lower-case letters g,j,p,q, and y; these are known as 'descenders' since they have 'tails' which descend below the normal display position. As can be seen from Fig.5, the descenders are stored in the ROM displaced upwards by two dots from their correct position. It is therefore necessary to employ additional circuitry to detect the presence of these particular characters, and artificially displace them downwards so that the tails appear below the line of the other characters in the normal way. When a descender has been detected, the row address supplied to the ROMs is reduced by two. This means that the incoming row address has to be two higher than normal (that is, two lines later than normal) before the character is displayed. The descender is thus displaced two lines downwards.

An inhibit terminal is provided in the circuit (Fig.13) which is normally earthed: however, if it is connected HIGH then the detect descender circuit is made inoperative and all characters are displayed in the positions shown in Fig.5.

The arithmetic unit, which is the second part of the circuit in Fig.13, provides the row address information for the two ROMs. An adder (package S) adds the appropriate numbers to the incoming row address, obtaining the row addresses for the display ROM and reference ROM sequentially. Since a 4-bit adder is used, adding 15 is equivalent to subtracting 1. Providing a descender has not been detected, the display ROM row address is the same as the incoming row address, and the reference ROM has 15 (odd field) or 1 (even field) added to provide its row address. When a descender has been detected, the arithmetic unit adds 14 (that is −2) to the incoming row address for the display ROM, and adds 13 (odd field) or 15 (even field) for the reference ROM.

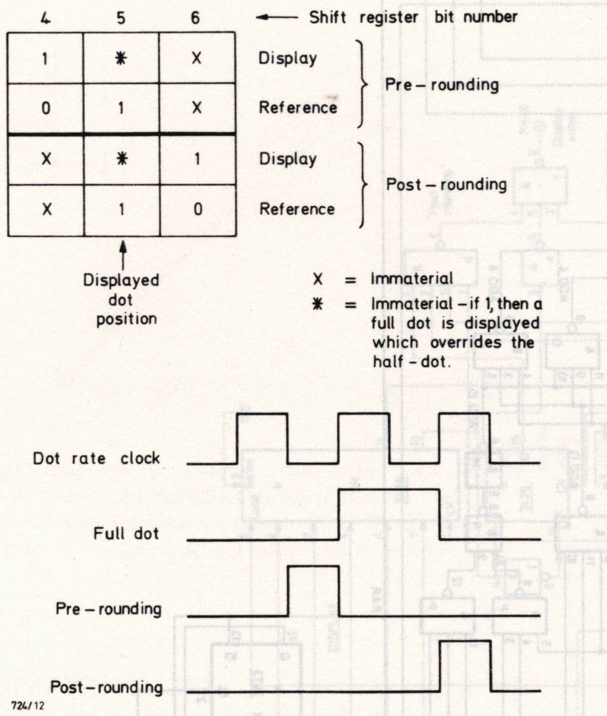


Fig.12 — Generation of pre-rounding and post-rounding information

These addresses are obtained sequentially using the clock signal AUL, which is normally HIGH and goes LOW for a short time during every character period. When AUL is LOW, the appropriate number to obtain the display ROM address is set up at the second input of the adder S. The correct row address appears at the output of the adder and is enabled into the latch T. When AUL returns HIGH, the latch is disabled, and the display ROM row address remains stored in the latch. At the same time, the correct number to calculate the reference ROM input is set up at the adder input, and the resulting output is applied directly to the reference ROM address inputs.

The ROMs themselves are p-channel enhancement-mode MOS devices, and are interfaced to the TTL circuitry in the rest of the character generator using the simple circuits shown in the inset of Fig.13. An 'address read' clock pulse RAR is required for the ROMs, and this is generated by the timing circuitry together with the AUL pulse mentioned previously. The timing circuitry requires initiate pulses from 50 to 450ns duration, at character rate (1MHz in the case of teletext).

Loading pulses for the output shift registers are generated by the monostable i from the positive edge of the character clock waveform. A display window enable is also provided, so that character data is generated only when required.

The ROMs are organised so that only six bits of the ASCII code are applied to the ROM inputs. There are two sets of five output pins generating two different characters simultaneously. An external multiplexer is therefore used to select which of the two characters is required (packages C, D, and E).

The 6-bit output shift registers are formed from a 5-bit shift register and a flip-flop; also a NAND gate f effectively performs an OR function of the display video and pre-rounding and post-rounding information from the previous NAND gates. Otherwise the operation of the output stage is identical to that of Fig.11. A printed-wiring board layout for Fig.13 is given in Ref.1, together with timing and other information.

The system described is only one method of achieving character rounding. If the character rate is sufficiently slow, it may be possible to access a single ROM twice in each character period. This would allow the display and reference dot information to be obtained sequentially with only one ROM.

Alternatively, it might be possible to organise a ROM in such a way that two consecutive lines of dot information were available simultaneously. However, even the simple system using two 7 X 5 ROMs and character rounding achieves the effect of a 14 X 10 ROM. This effectively means that the ROM storage space required is halved, that is:

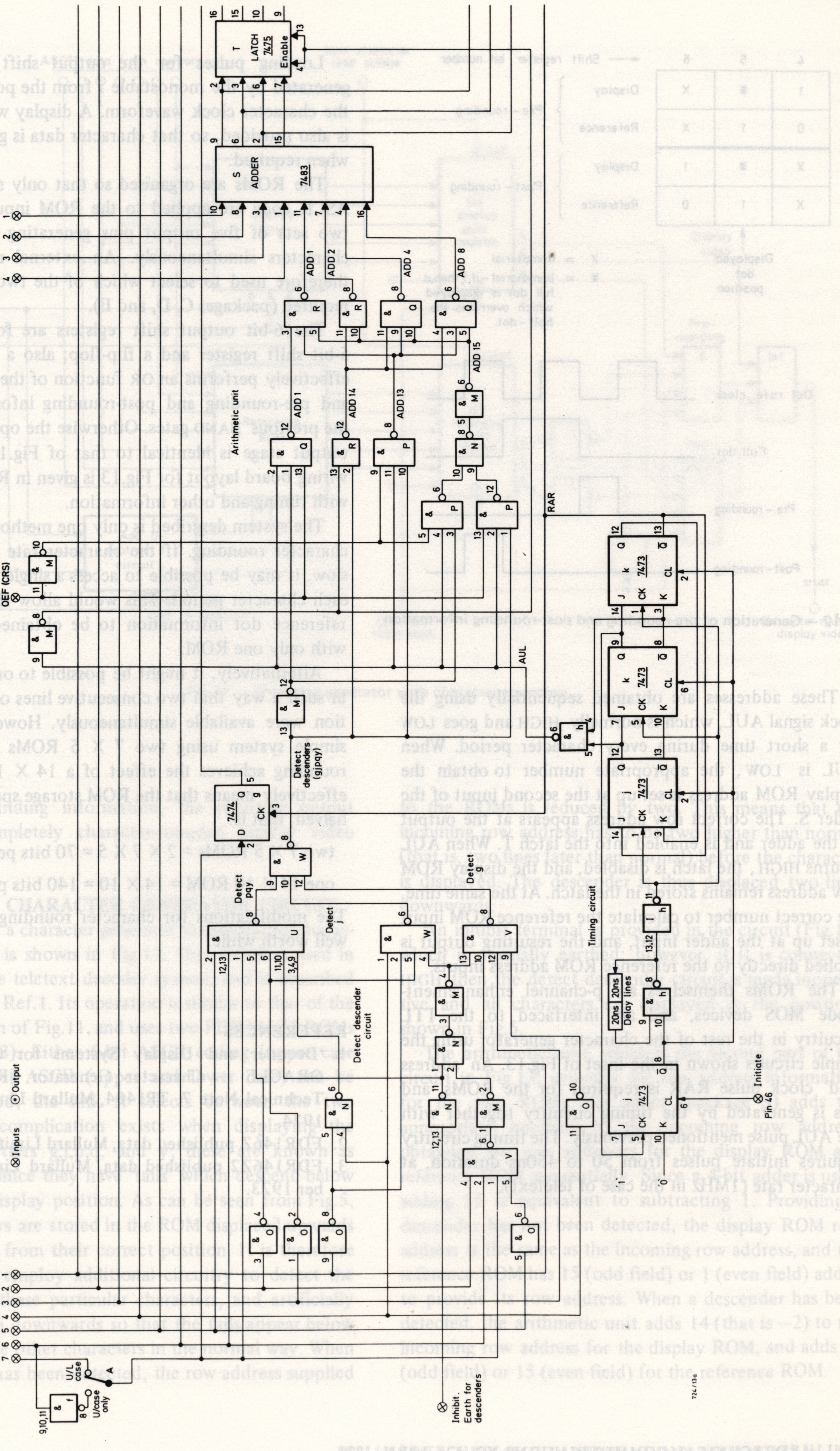
two 7 X 5 ROMs = 2 X 7 X 5 = 70 bits per character,

one 14 X 10 ROM = 14 X 10 = 140 bits per character.

The modifications for character rounding are therefore well worth while.

REFERENCES

1. 'Decoder and Display Systems for CEEFAX and ORACLE – Character Generator (ROM) Board', Technical Note 7, TP1404, Mullard Limited, October 1974.
2. FDR146Z published data, Mullard Limited, July 1971.
3. FDR146Z2 published data, Mullard Limited, December 1973.


LATCH
7475
T
Enable
ADDER
7483
S
Pin 76 75 74 73
Row address
ADD 1
ADD 2
ADD 4
ADD 8
ADD 15
ADD 14
ADD 13
Arithmetic unit
Pin 71 ODD/EVEN Field (ODF) (CRS)
Detect descenders (gjpqy)
7474
Detect pqy
Detect gj
Detect descender circuit
Pin 26 27 28 29 30 31 32
ASCII Data from Memory
U/L case
Upper case only
Inhibit. Earth for descenders
RAR
AUL
7473
Timing circuit
20ns
Delay lines
Initiate
Pin 46
724/13a

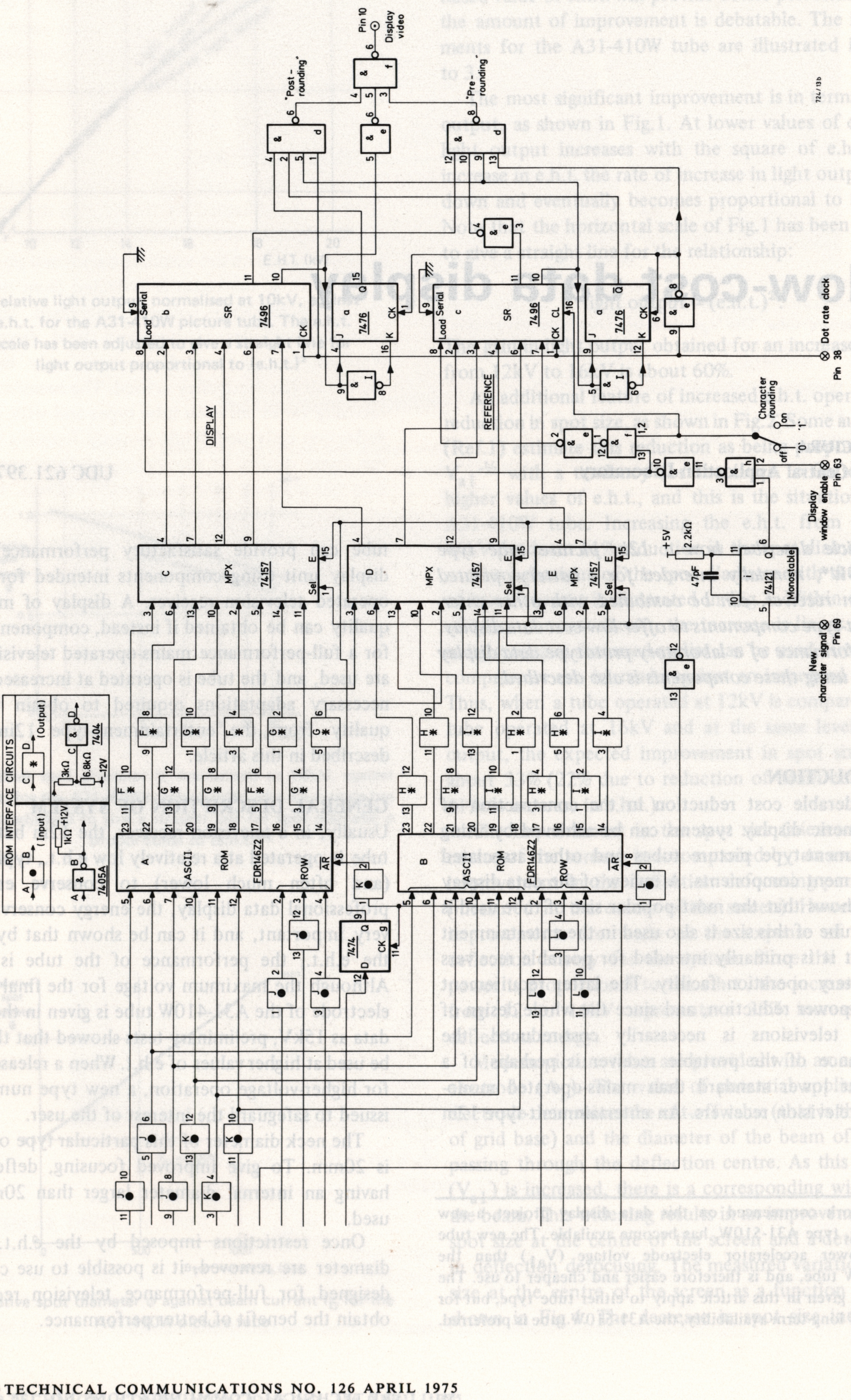

Pin 10
Display video
'Post-rounding'
'Pre-rounding'
SR
Load Serial
7496
7476
DISPLAY
REFERENCE
MPX
74157
Sel
Dot rate clock
Pin 38
Character rounding
on
off
Display window enable
Pin 63
+5V
2.2kΩ
47pF
74121
Monostable
New character signal
Pin 69
ROM INTERFACE CIRCUITS
(Output)
(Input)
7404
7405A
+12V
3kΩ
6.8kΩ
1kΩ
ROM
ASCII
ROW
AR
FDR146Z2
B
C
D
E
F
G
H
I
724/13b

Fig.13 – Character generator circuit

A low-cost data display

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UDC 621.397.13 [659.2]

The article describes how a 12in picture tube type A31-410W, normally intended for a battery-operated television receiver, can be combined with other entertainment-type components to offer low-cost data display. The performance of a laboratory prototype data display monitor using these components is also described.*

INTRODUCTION

A considerable cost reduction in the construction of alphanumeric display systems can be achieved by using entertainment-type picture tubes and other associated entertainment components. A review of the data display market shows that the most popular size of tube used is 12in. A tube of this size is also used in the entertainment field, but it is primarily intended for portable receivers with battery operation facility. The latter requirement calls for power reduction, and since the whole design of portable televisions is necessarily cost-reduced, the performance of the portable receiver is perhaps of a somewhat lower standard than mains-operated monochrome television receivers. An entertainment-type 12in tube can provide satisfactory performance in a data display unit using components intended for a battery-operated television receiver. A display of much higher quality can be obtained if instead, components intended for a full-performance mains-operated television receiver are used, and the tube is operated at increased e.h.t. The necessary adaptations required to obtain this higher quality from the entertainment-type 12in tube are described in this article.

GENERAL DESCRIPTION OF SYSTEM

Usually, in a television receiver, the 12in battery-driven tube is operated at a relatively low e.h.t., typically 12kV (and often much lower) to conserve energy. For professional data display, the energy conservation is not very important, and it can be shown that by increasing the e.h.t., the performance of the tube is improved. Although the maximum voltage for the final accelerator electrode of the A31-410W tube is given in the published data as 15kV, preliminary tests showed that the tube can be used at higher values of e.h.t. When a release is granted for higher-voltage operation, a new type number will be issued to safeguard the interest of the user.

The neck diameter of this particular type of 12in tube is 20mm. To give improved focusing, deflection coils having an internal diameter larger than 20mm can be used.

Once restrictions imposed by the e.h.t. and neck diameter are removed, it is possible to use components designed for full-performance television receivers and obtain the benefit of better performance.

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*Since work commenced on this data display project, a new 12in tube, type A31-510W, has become available. The new tube has a lower accelerator electrode voltage (V_{a1}) than the A31-410W tube, and is therefore easier and cheaper to use. The principles given in this article apply to either tube type, but for reasons of long-term availability, the A31-510W tube is preferred.

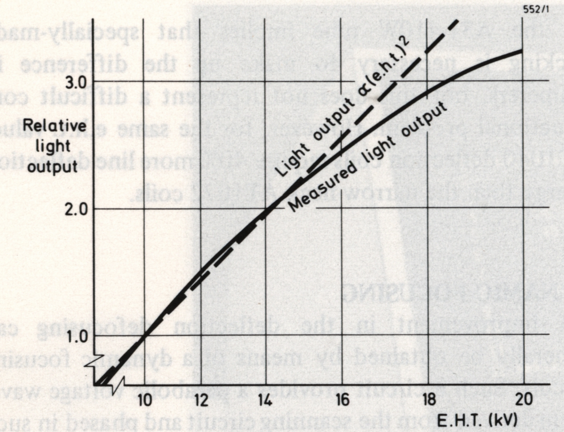

Fig.1 — Relative light output, normalised at 10kV, against e.h.t. for the A31-410W picture tube. The e.h.t. scale has been adjusted to give a straight line for light output proportional to (e.h.t.)^2

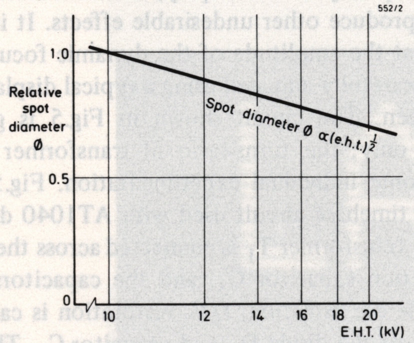

Fig.2 — Relative spot diameter ϕ, normalised at 10kV, against e.h.t. for the A31-410W picture tube. The e.h.t. scale has been adjusted to give a straight line for spot diameter ϕ proportional to (e.h.t.)^{½}

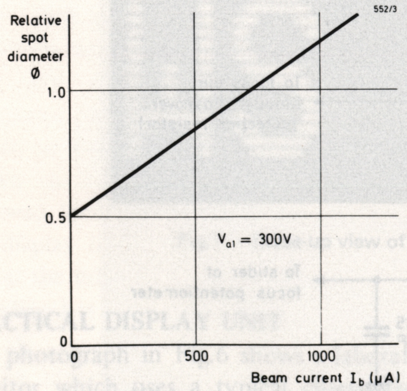

Fig.3 — Relative spot diameter ϕ against beam current I_b for the A31-410W picture tube

TUBE PERFORMANCE

It is generally accepted that a picture tube operated at a raised value of e.h.t. will provide better performance, but the amount of improvement is debatable. The improvements for the A31-410W tube are illustrated in Figs.1 to 3.

The most significant improvement is in terms of light output, as shown in Fig.1. At lower values of e.h.t. the light output increases with the square of e.h.t.; with increase in e.h.t. the rate of increase in light output slows down and eventually becomes proportional to the e.h.t. Note that the horizontal scale of Fig.1 has been adjusted to give a straight line for the relationship:

$$\text{light output} \propto (\text{e.h.t.})^2.$$

The gain in light output obtained for an increase in e.h.t. from 12kV to 16kV is about 60%.

An additional feature of increased e.h.t. operation is a reduction in spot size, as shown in Fig.2. Some authorities (Ref.1) estimate this reduction as being proportional to $V_{a1}^{-½}$ with a tendency for the curve to flatten out at higher values of e.h.t., and this is the situation for the A31-410W tube. Increasing the e.h.t. from 12kV to 16kV produces 11% reduction in the spot diameter.

The behaviour of the spot diameter with the increase of beam current is illustrated in Fig.3. Within the range of beam currents shown, the increase is linear. The gain in light output discussed earlier can be used directly, or a compromise can be made against an improved spot size. Thus, when a tube operated at 12kV is compared with a tube operated at 16kV and at the same level of light output, the expected improvement in spot size can be about 33% (22% due to reduction of beam current and 11% to increase in e.h.t.).

The improvement in the spot size (measured at the centre of the screen) is accompanied by an even greater improvement in the deflection defocusing performance (measured in the corner of the screen). However, these improvements are made at the expense of increased deflection energy for the system. Since the deflection power is proportional to the e.h.t., the increase in e.h.t. from 12 to 16kV represents a 33% increase in the deflection energy.

Modern picture tubes are provided with an accelerator electrode (A_1). The value of potential applied to this electrode determines the cut-off value (that is the 'length' of grid base) and the diameter of the beam of electrons passing through the deflection centre. As this potential (V_{a1}) is increased, there is a corresponding widening of the beam. This widening results in an improvement in the spot size at the centre of the screen and a deterioration in deflection defocusing. The measured variation of spot size at the centre of the screen as a function of V_{a1} is shown in Fig.4. The decrease in spot size indicated in

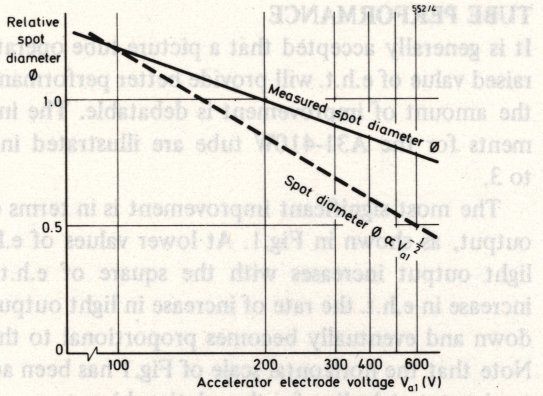

Fig.4 – Relative spot diameter ϕ, normalised at 100V, against accelerator electrode voltage V_{a1} for the A31-410W picture tube. The V_{a1} scale has been adjusted to give a straight line for spot diameter ϕ proportional to $V_{a1}^{-1/2}$

Fig.4 is estimated by some authorities (Ref.1) to be proportional to $V_{a1}^{-1/2}$ with a flattening-out of the curve at higher values of V_{a1}. (The same estimate for decreased spot size was given earlier for increased e.h.t.) As shown in Fig.4, this estimate does not entirely apply to the A31-410W tube, but there is a general trend of this nature. Operation of V_{a1} above, say, 400V does not bring any particular benefit and can make deflection defocusing worse.

The deflection defocusing performance of a picture tube is to a large extent a function of the quality of the deflection coil. Subjective tests have shown that a better performance can be obtained using AT1040 coils designed for a full-performance monochrome tv receiver (28mm diameter tube neck) than with the AT1072 coils specifically designed for so-called 'tinyvision' applications (20mm diameter tube neck). The use of the former coils on the A31-410W tube implies that specially-made packing is necessary to make up the difference in diameters, but this does not represent a difficult constructional problem. However, for the same e.h.t. value, AT1040 deflection coils require 40% more line deflection energy than the narrow-neck AT1072 coils.

DYNAMIC FOCUSING

An improvement in the deflection defocusing can generally be obtained by means of a dynamic focusing circuit. Such a circuit provides a parabolic voltage waveform derived from the scanning circuit and phased in such a way that, as the beam is deflected from the centre of the screen, the focus voltage is increased. Theoretically, parabolic voltages at line and field frequencies are required, but in most applications only the parabolic voltage at line frequency is used. The benefit of dynamic focusing varies between tube types and with the types of deflection coils used. While dynamic focusing can improve the focus quality of the display, indiscriminate application can produce other undesirable effects. It is for this reason that the amplitude of the dynamic focus voltage has to be carefully adjusted using a typical display on the CRT screen. The circuit shown in Fig.5 is given for guidance only; the turns-ratio of transformer T_1 may require some individual experimentation. Fig.5 applies to a line timebase circuit used with AT1040 deflection coils. The transformer T_1 is connected across the existing 'S' correction capacitor C_3, and the capacitors C_1 and C_2 provide d.c. isolation. D.C. restoration is carried out by means of the diode D_1 and capacitor C_4. The resulting waveform is added to the existing d.c. focus voltage which is normally available at the slider of the focus potentiometer.

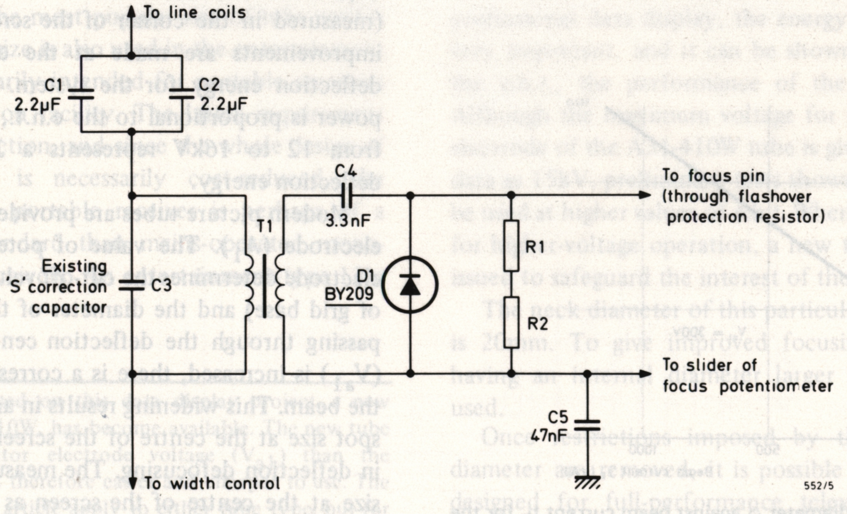
To line coils
C1
2.2µF
C2
2.2µF
C4
3.3nF
T1
Existing 'S' correction capacitor
C3
D1
BY209
R1
R2
To focus pin (through flashover protection resistor)
To slider of focus potentiometer
C5
47nF
To width control
552/5

Fig.5 – Suggested dynamic focus circuit for use with the data display monitor

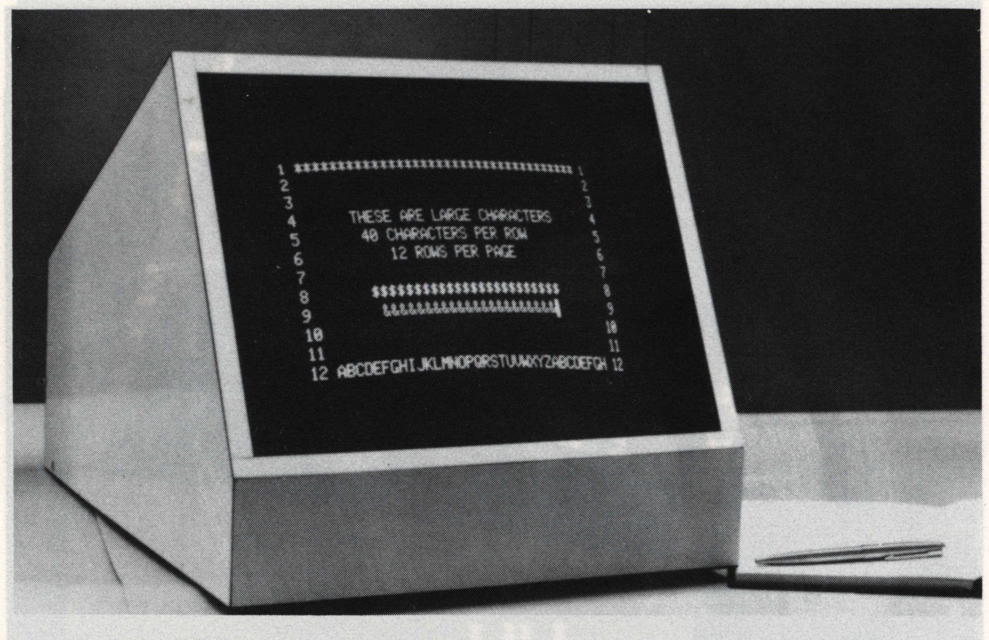
THESE ARE LARGE CHARACTERS
40 CHARACTERS PER ROW
12 ROWS PER PAGE
ABCDEFGHIJKLMNOPQRSTUVWXYZABCDEFGH

Fig.6 – Laboratory prototype data display monitor with large characters displayed, but without character rounding applied to the characters

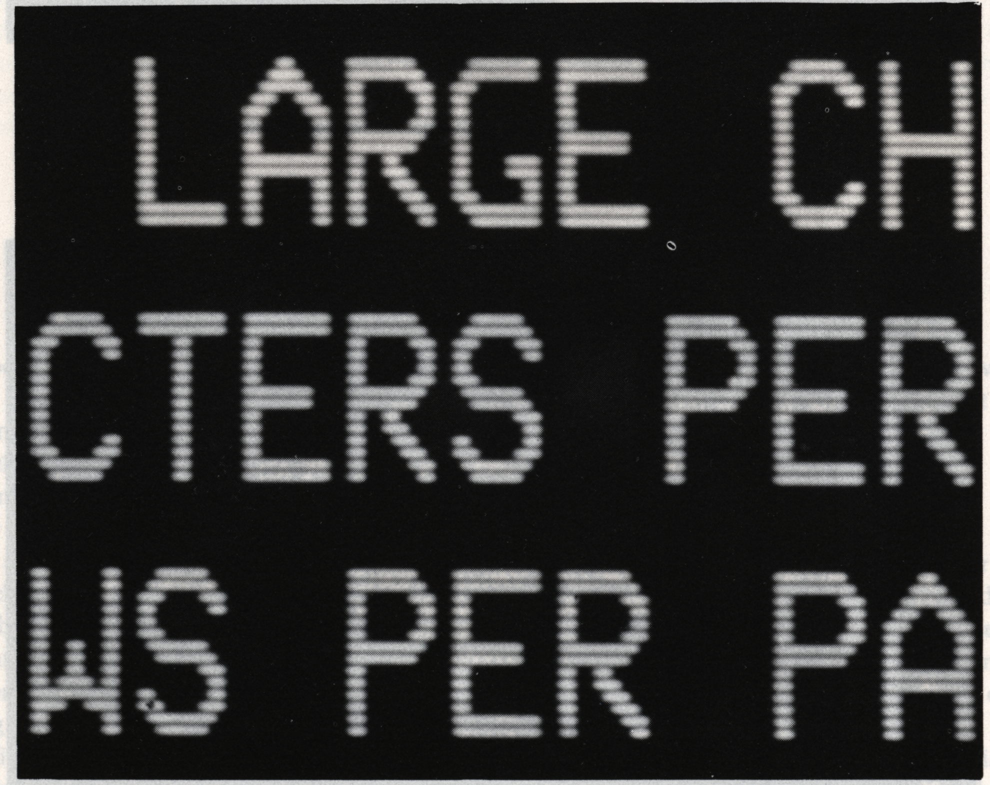

Fig.7 – Close-up view of part of the display shown in Fig.6. Character rounding has been applied to the characters

PRACTICAL DISPLAY UNIT

The photograph in Fig.6 shows a laboratory prototype monitor which uses a typical chassis from a standard receiver. In the design of the cabinet for the monitor, the aim was to provide a low profile, with the screen inclined at an angle suitable for viewing at close quarters while sitting at a desk. In front of the tube a tinted Perspex panel is placed. Its function is two-fold: to provide an enhancement of contrast for the display, and to protect the viewer from glass splinters in the very unlikely event

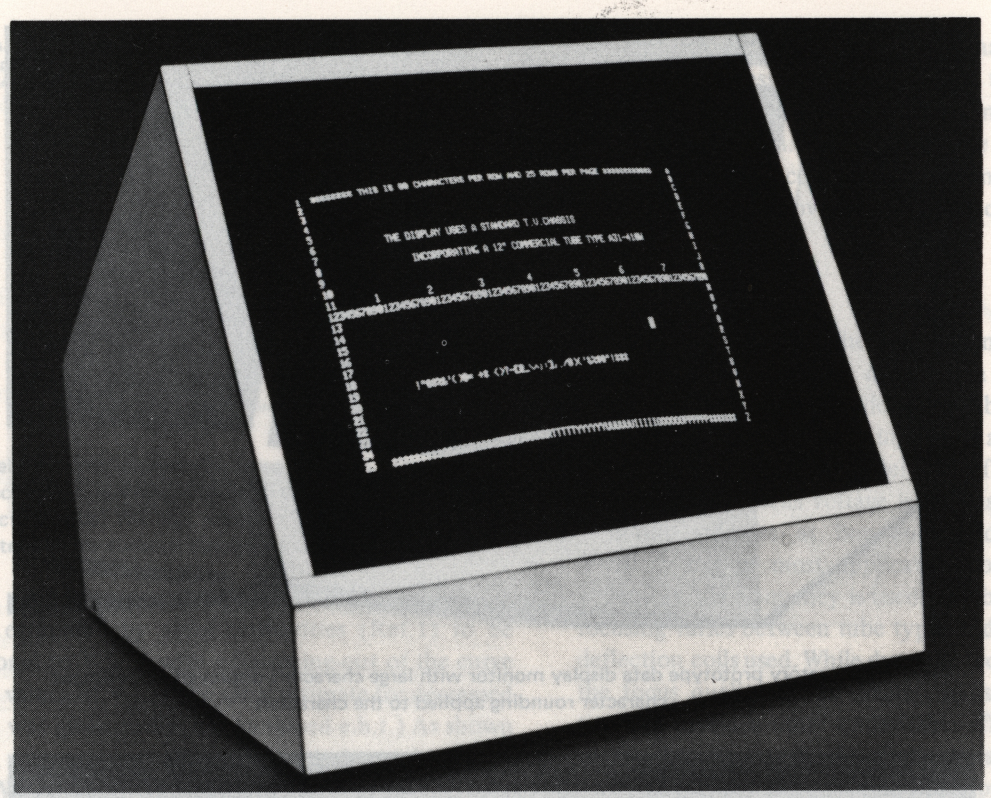

Fig.8 – Data display monitor with small characters displayed

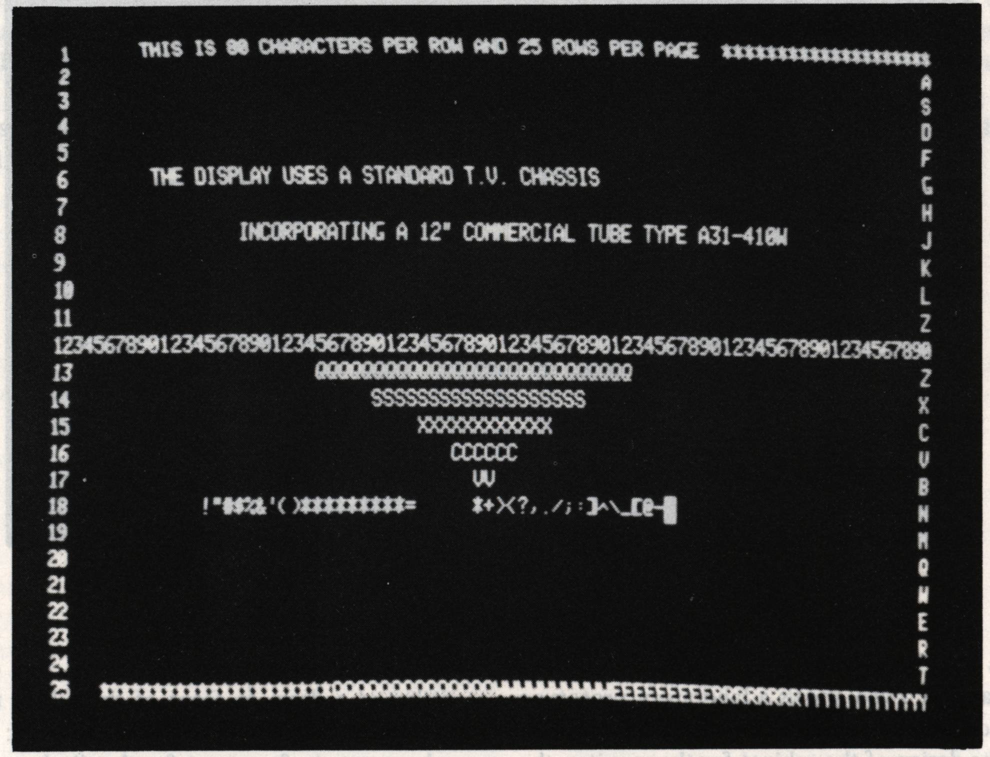
THIS IS 80 CHARACTERS PER ROW AND 25 ROWS PER PAGE
THE DISPLAY USES A STANDARD T.V. CHASSIS
INCORPORATING A 12" COMMERCIAL TUBE TYPE A31-410W
12345678901234567890123456789012345678901234567890123456789012345678901234567890
CCCCCC
VV

Fig.9 – View of monitor screen with Perspex panel removed, and small characters displayed

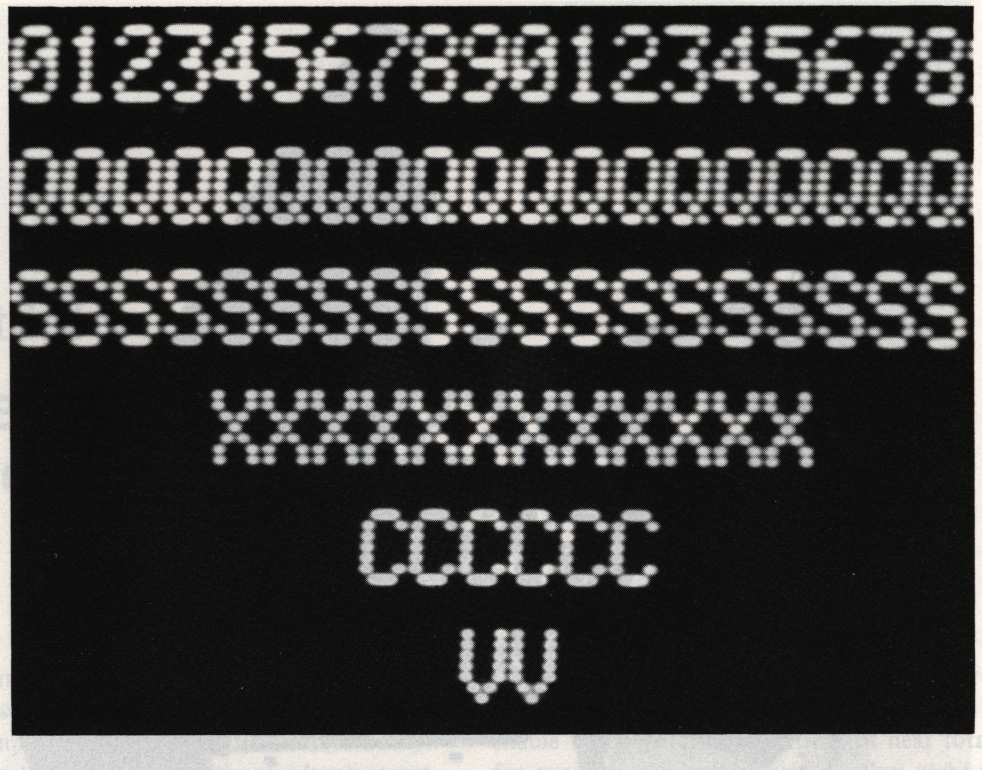

Fig.10 – Close-up view of part of the display shown in Fig.9

of picture tube implosion. Large characters (40 characters per row, and 12 rows per page) are shown displayed on the screen in Fig.6. No character rounding has been applied to the numbers and letters in this display: character rounding is a facility which can be built into the character generator of the display unit (see Ref.2). Fig.7 shows a close-up view of part of the display in Fig.6, with character rounding applied. The characters are (at the tube face) 8mm high by 5mm wide.

A view of the monitor with small characters (80 characters per row, and 25 rows per page) displayed is shown in Fig.8. Another display of small characters is shown in Fig.9, where the Perspex panel has been removed from the monitor. A close-up view of part of the display in Fig.9 is shown in Fig.10. The characters are (at the tube face) 4mm high by 3mm wide. Character rounding has been applied to the displays in Figs. 8, 9, and 10.

The possible construction of a data display unit is indicated by the side view in Fig.11 of the laboratory prototype monitor with the cover removed. The overall dimensions of the monitor with the cover in position (see Figs.6 and 8) are 415 × 335mm at the base, and 320mm high.

APPLICATIONS

The main application for which a monitor of this type is intended is that of the VDU in existing data display or computer terminals. In these terminals there is normally available the appropriate display information derived from a character generator driven by the data system or keyboard.

A further application is that of specialised teletext (Refs.3, 4, 5, 6, and 7) display units where, in future, special services supplied by CEEFAX (BBC) or ORACLE (IBA) may be made available for professional uses. Further developments will probably include independent teletext systems, probably line-connected, in which the data is essentially of the teletext type. The display unit described here provides an ideal compromise of cost and quality of display for such specialised uses.

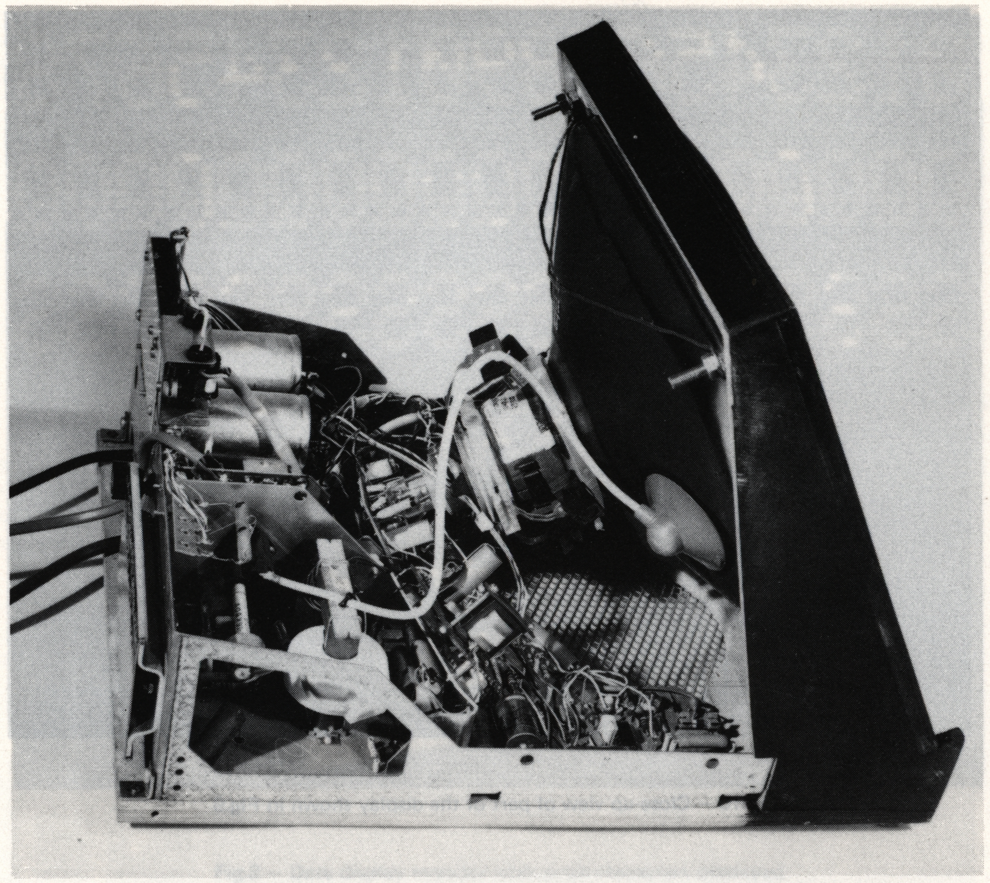

Fig.11 — Side-view of laboratory prototype monitor with cover removed

REFERENCES

1. ZWORYKIN, V.K. and MORTON, G.A., 'Television', 2nd Edition, John Wiley and Sons Inc., New York, 1954, Chap.12, Sec.12.3, page 452.
2. KINGHORN, J.R., 'Character Rounding for Alphanumeric Video Display', **Mullard Technical Communications,** Vol.13, No.126, April 1975, p.230.
3. 'Decoder and Display Systems for CEEFAX and ORACLE: Features of Unified Transmission System and Mullard Decoder Organisation', Technical Note 4, TP1403/1, Mullard Limited, 1974.
4. 'Decoder and Display Systems for CEEFAX and ORACLE: Character Generator (ROM) Board', Technical Note 7, TP1404, Mullard Limited, 1974.
5. 'Decoder and Display Systems for CEEFAX and ORACLE: Memory and Address Circuits', Technical Note 11, TP1405, Mullard Limited, 1974.
6. 'Decoder and Display Systems for CEEFAX and ORACLE: Timing Chain', Technical Note 12, TP1406, Mullard Limited, 1974.
7. 'Decoder and Display Systems for CEEFAX and ORACLE: Caption Blanking Circuit', Technical Note 17, TP1407, Mullard Limited, 1975.

Product Information:

Image intensifiers: aids to night vision

Image intensifiers are electron-optical devices in which the image of a scene or object is focused on a photocathode at the input and then intensified electronically. The intensified image is viewed directly on a luminescent screen at the output. The devices described here are all for use in passive systems; that is, they rely for their operation on available light and do not require the object to be illuminated with infrared radiation. By amplifying the light level by up to one hundred thousand times, they enable clear vision in conditions of near total darkness, for example, on an overcast moonless night (see Fig.1).

In this short article, the three basic types of image intensifier are described and brief data for individual types is given.

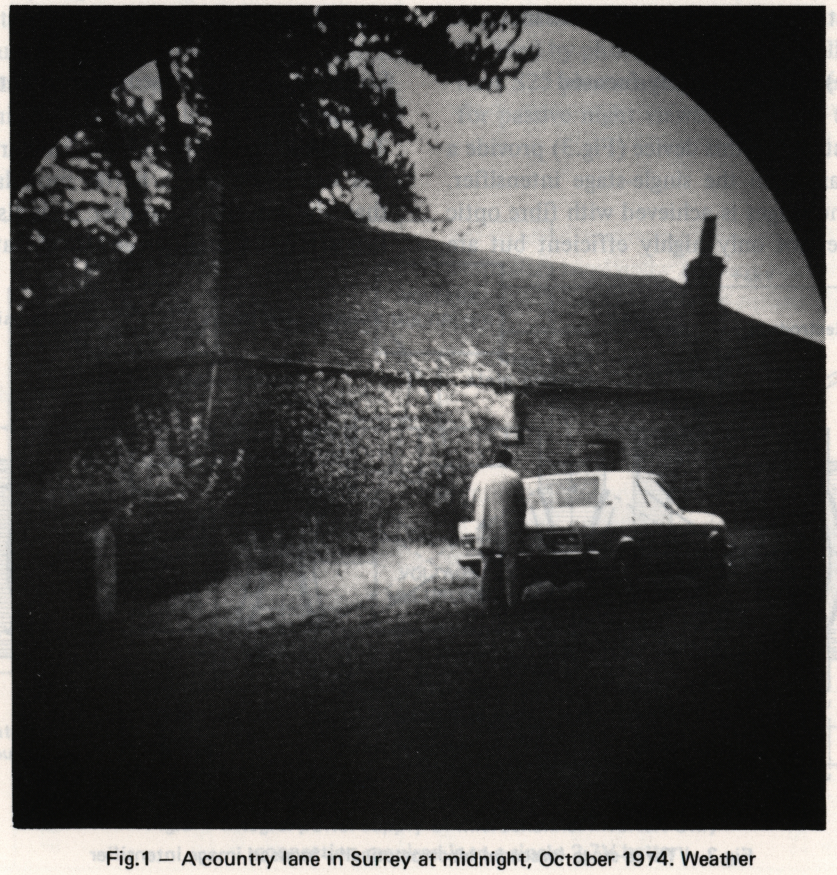

Fig.1 — A country lane in Surrey at midnight, October 1974. Weather conditions: overcast and raining

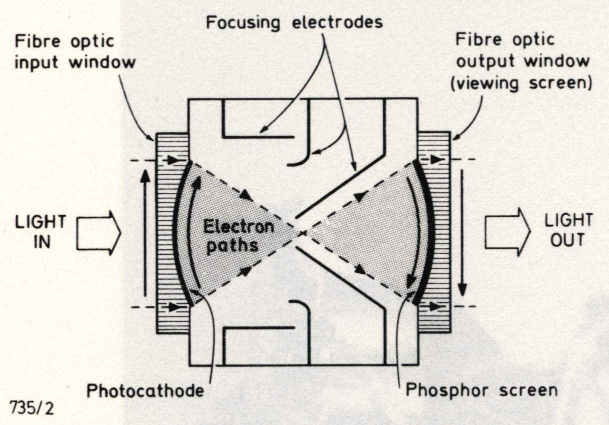
Fibre optic input window
Focusing electrodes
Fibre optic output window (viewing screen)
LIGHT IN
Electron paths
LIGHT OUT
Photocathode
Phosphor screen
735/2

Fig.2 — Single-stage electrostatically-focused image intensifier

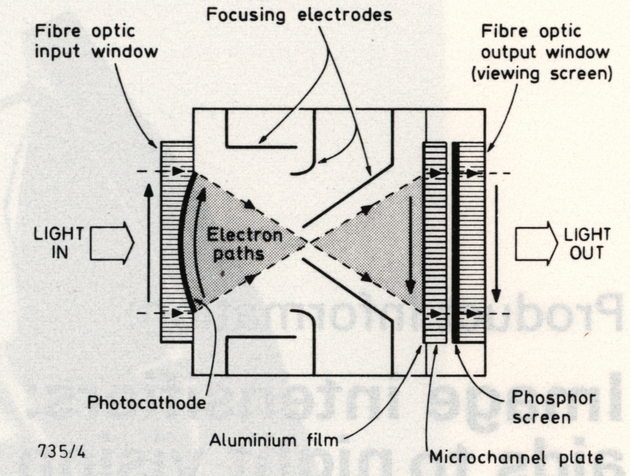
Fibre optic input window
Focusing electrodes
Fibre optic output window (viewing screen)
LIGHT IN
Electron paths
LIGHT OUT
Photocathode
Phosphor screen
Aluminium film
Microchannel plate
735/4

Fig.4 — Electrostatically-focused microchannel inverter image intensifier

TYPES OF IMAGE INTENSIFIER

Single-stage electrostatically-focused image intensifier

Light from the subject is focused on to the photocathode by means of an objective lens, and a corresponding electron pattern is emitted (see Fig.2). The electrons are accelerated through a potential of several thousand volts and strike the phosphor viewing screen, where they form a highly-intensified image of the original subject. The new image is inverted as required in the overall system design, hence the cost of optical inversion is not incurred.

Three-stage (cascade) electrostatically-focused image intensifier

The three cascaded stages of this device (Fig.3) provide a higher luminance gain than the single-stage intensifier. Coupling between the stages is achieved with fibre optic faceplates which are not only highly efficient but are compact and designed to be compatible with the electrostatic focusing system.

Since there are three inverting stages, the final image is inverted and, as with the single-stage intensifier, the user is spared the cost of optical inversion. Also, in common with the single-stage intensifier, the resolution is very good.

Types with automatic brightness control (ABC) are available, either with an integral power supply or for use with an external oscillator.

Electrostatically-focused microchannel inverter image intensifier

This device (see Fig.4) has a similar luminance gain, but less distortion and a better modulation transfer factor than the cascade intensifier. It is also physically smaller. It is in effect a single-stage electrostatically-focused image intensifier with a microchannel plate electron-multiplier situated very close to the viewing screen.

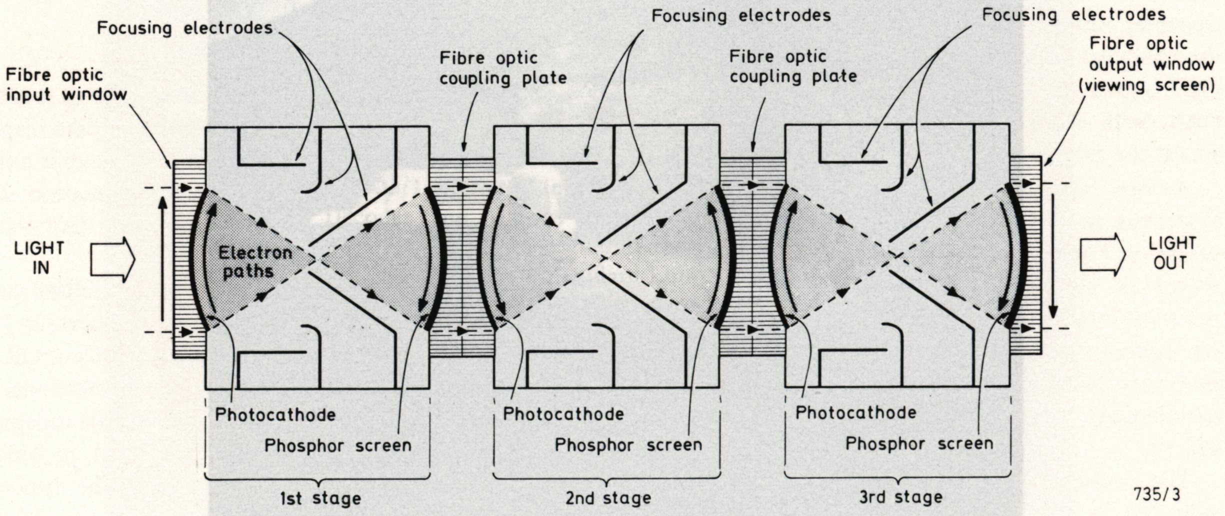
Focusing electrodes
Fibre optic input window
Fibre optic coupling plate
Focusing electrodes
Fibre optic coupling plate
Focusing electrodes
Fibre optic output window (viewing screen)
LIGHT IN
Electron paths
LIGHT OUT
Photocathode
Phosphor screen
Photocathode
Phosphor screen
Photocathode
Phosphor screen
1st stage
2nd stage
3rd stage
735/3

Fig.3 — Three-stage (cascade) electrostatically-focused image intensifier

Channel plates comprise millions of minute 'channels' or tubes running parallel to each other between the two surfaces of the plate. Each channel, by virtue of a high potential applied between its ends and an emissive internal coating, acts as an electron multiplier. The density of the electron image on the output side of the plate is therefore much greater than on the input side, and a bright image is formed on the luminescent viewing screen.

A useful property is that individual channels can saturate without affecting neighbouring channels. Bright point sources of light are thus suppressed without reduction in gain in darker parts of the image.

A distinguishing feature of the electrostatically-focused channel plate intensifier is that the design allows a metallic aluminium film to be deposited on the input side of the channel plate. This has the effect of equalising gain at all points on the plate and so preventing an area of reduced gain, or 'black spot', at the centre of the image.

The aluminium film also reduces the background noise of the tube. Furthermore, it protects the photocathode from positive ions produced in the channel plate, and so contributes to long life, even at high cathode illumination. In fact, under normal operating conditions, tube life is likely to be many thousands of hours.

As with the intensifiers previously described, the electrostatically-focused channel plate device produces an inverted image, and no fibre optic 'twister' or optical inverting lens is required. It is available with variable gain and automatic brightness control. There are also types with an integral power supply (see Fig.5) which are ideally suited for night vision goggles and similar applications where minimum size and weight are necessary.

CHARACTERISTICS AND CHOICE OF TUBE

When deciding on an image intensifier for a particular application, there is unfortunately no overall figure of merit which equipment designers can use as a guide, and there is certainly no single characteristic on which a choice can be based. Obviously, however, choice depends on the fitness of a particular intensifier for the particular application. Therefore, Mullard image intensifiers are designed to give the best possible overall performance in specific fields of application. It is not claimed that they offer the highest luminance gain or the 'best' characteristic of any kind. What is offered, however, is a range of devices in which each characteristic is considered, not in isolation, but in its effect on total tube performance. Extremely high photocathode sensitivity, for instance, has little meaning if it contributes to an unsatisfactorily high noise level or is associated with a poor modulation transfer factor.

It is worth bearing in mind four primary characteristics and their inter-relationship when initially assessing an image intensifier. These are:

Photocathode spectral response

Defined by photocathode type. Mullard image intensifiers have S25 photocathodes which give the best performance for passive night viewing systems; that is, the maximum

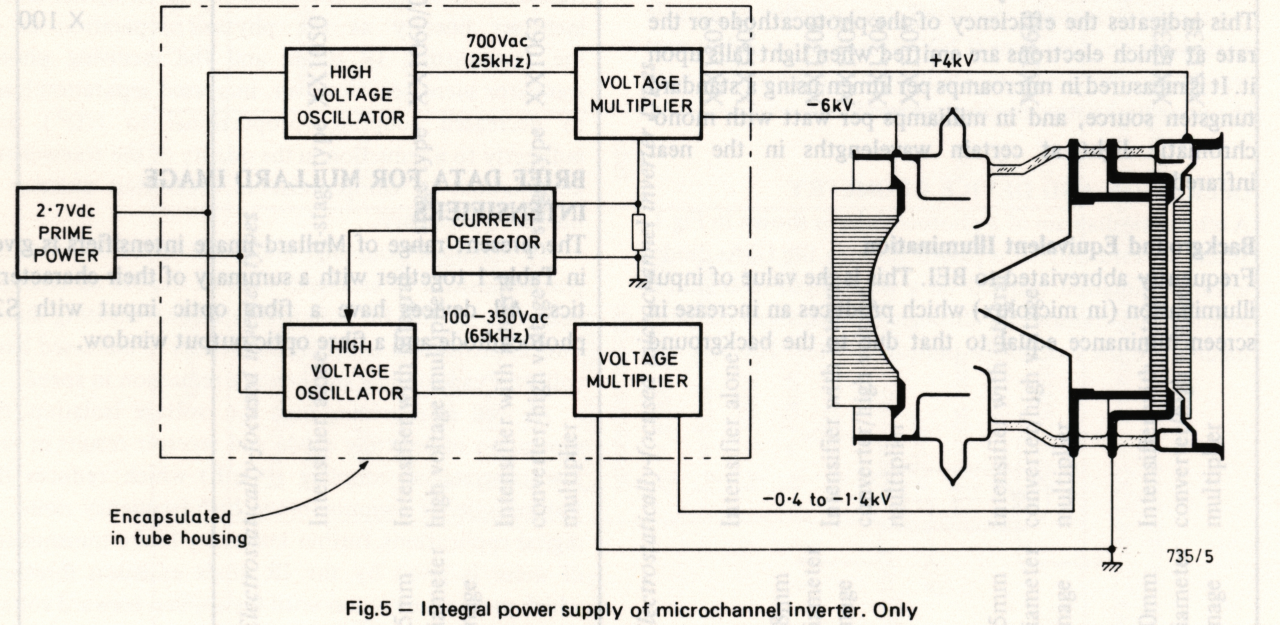
700Vac (25kHz)
HIGH VOLTAGE OSCILLATOR
VOLTAGE MULTIPLIER
+4kV
−6kV
2·7Vdc PRIME POWER
CURRENT DETECTOR
100−350Vac (65kHz)
HIGH VOLTAGE OSCILLATOR
VOLTAGE MULTIPLIER
−0·4 to −1·4kV
Encapsulated in tube housing
735/5

Fig.5 — Integral power supply of microchannel inverter. Only connection required is to a single 2·7V battery

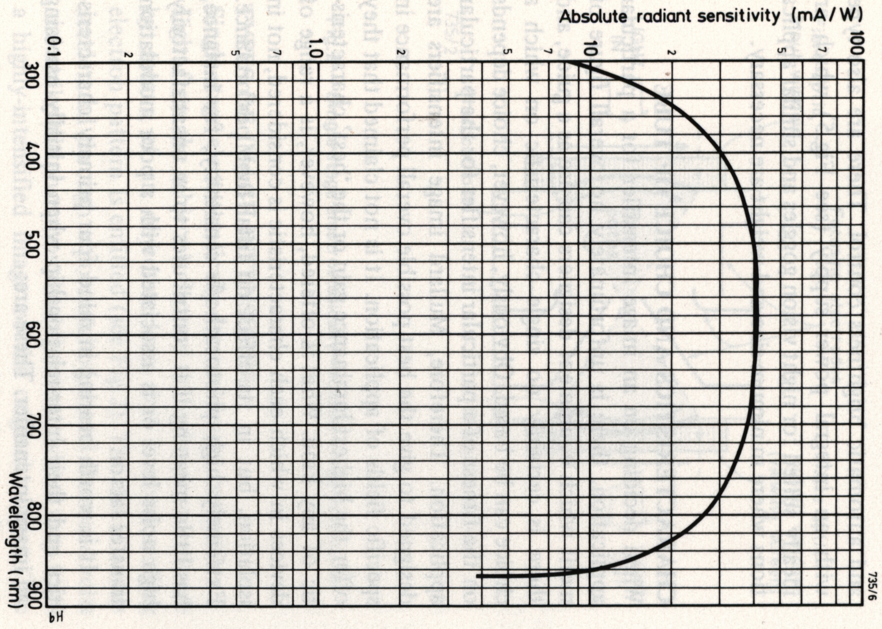

Fig.6 — Typical spectral response of S25 photocathode

response to visible light, with appreciable response in the near infrared part of the spectrum (see Fig.6).

Photocathode sensitivity
This indicates the efficiency of the photocathode or the rate at which electrons are emitted when light falls upon it. It is measured in microamps per lumen using a standard tungsten source, and in milliamps per watt with monochromatic light at certain wavelengths in the near infrared.

Background Equivalent Illumination
Frequently abbreviated to BEI. This is the value of input illumination (in microlux) which produces an increase in screen luminance equal to that due to the background noise generated in the device. The measurement is made with the image intensifier operated at its maximum luminance gain.

Luminance gain
This is expressed as a number, being the ratio:

$$\pi \times \frac{\text{luminous intensity of viewing screen (cd/m}^2\text{)}}{\text{illumination of photocathode (lux)}},$$

(using a standard tungsten source.)

Three other useful characteristics are:

Limiting resolution
Centre resolution is measured at the centre of the photocathode, and edge resolution is measured at a specified radial distance from the centre. The 'line pairs/mm' figures refer to a black and white bar pattern with a contrast approaching 100%.

Modulation transfer factor
This is a comparison of the contrast of the 'input image' with the contrast of the 'output image'. It is measured using an object in which the transition between light and dark parts is sinusoidal, and it is quoted for various values of 'spatial frequency' (cycles per mm).

Distortion
Percentage distortion is given by:

$$\left(\frac{\text{Magnification of 'large' circle on photocathode}}{\text{Magnification of 'small' circle on photocathode}} - 1\right) \times 100$$

BRIEF DATA FOR MULLARD IMAGE INTENSIFIERS
The present range of Mullard image intensifiers is given in Table 1 together with a summary of their characteristics. All devices have a fibre optic input with S25 photocathode and a fibre optic output window.

TABLE 1

Abridged Data for Image Intensifiers

				Mode of operation	Input window size and surface shape	Photocathode		Luminance gain (typical)	Distortion	Overall dimensions		Weight
						sensitivity (2856K) typical (μA/lm)	Extended red performance		(%)	Diam. (mm)	Length (mm)	(g)
Electrostatically-focused inverter types												
					25mm							
	Intensifier alone	1-stage type	XX1050	Gain dependent on power supply	Plane	230	Yes	>100	7·0	50	60	145
25mm diameter image	Intensifier with integral high voltage multiplier	3-stage type	XX1060/01	ABC characteristic. External oscillator required	Plane	275	Yes	70 000	20	70	195	880
	Intensifier with integral converter/high voltage multiplier	3-stage type	XX1063	Full ABC characteristic	Plane	275	Yes	70 000	20	70	195	880
Electrostatically-focused microchannel inverter types												
					18mm							
18mm diameter image	Intensifier alone		XX1302	Gain dependent on external power supply	Plane	225	Yes	50 000	14	45	44	70
			XX1303		Concave	225	Yes		14	45	47	175
					18mm							
	Intensifier with integral converter/high voltage multiplier		XX1306	Full ABC characteristic	Plane	225	Yes	<50 000	14	53	47	175
			XX1307		Concave	225	Yes	<50 000	14	53	50	175
			XX1308		Plane	225	Yes	80 000	14	53	47	175
			XX1309		Concave	225	Yes	80 000	14	53	50	175
					25mm							
25mm diameter image	Intensifier with integral converter/high voltage multiplier		XX1360	Full ABC characteristic. Gain variable by external controls	Plane	225	Yes	>50 000	5·5	60	76	325
					50mm					Rectangular package		
40mm diameter image	Intensifier with integral converter/high voltage multiplier		XX1332	Full ABC characteristic	Plane	230	Yes	>50 000	10	92 × 66 × 101		1000
			XX1333		Concave					92 × 66 × 103		

Product Information:
Photocouplers

Photocouplers (optically-coupled isolators) provide an excellent means for transferring information between two circuits electrically isolated from each other. They offer high input-to-output isolation (up to 4kV) and low coupling capacitance (typically 1pF). Furthermore, they have a fast response (data rates up to 100kbits/s), and are TTL compatible. As replacements for electromechanical relays, they are faster, smaller, and more reliable.

The Mullard range of photocouplers comprises types having input-to-output isolation voltages ranging from 1500V peak up to 4000V peak, and forward current transfer ratios from 20% up to 600%. Each device consists of a GaAs infrared emitting diode and a silicon n-p-n phototransistor, mounted close together in a single encapsulation. One type (CNY48) includes an additional transistor, connected in Darlington configuration with the phototransistor, to give increased gain.

OPERATION AND DEVICE GEOMETRY

A schematic diagram of a photocoupler is shown in Fig.1. When forward current is passed through the GaAs diode, infrared radiation centred on a wavelength of 0·9μm is emitted and transmitted through a transparent coupling medium to the base of the phototransistor. The base can be left floating or connected to the emitter. In the latter case, the detector operates as a photodiode and the output current is simply that due to photo-generation. If, however, the base is left open-circuit, the holes generated cause the base-emitter junction to become forward-biased. This results in increased collector-emitter current, several hundred times that obtained with the earthed-base configuration, but at the expense of a slower response. Operation with base open-circuit is the most common configuration.

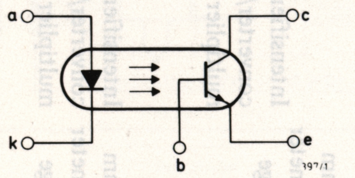

Fig.1 — Schematic diagram of photocoupler

The most important application of the photocoupler is to provide the highest possible level of isolation between two sub-systems while at the same time enabling efficient transmission of data. The insulation given by the device increases linearly as the physical separation D of the transmitting IR diode and the receiving phototransistor increases. However, increased separation leads to decreased coupling (proportional to $1/D^2$), and indirectly to a reduction in the quality of the transmitted information. A compromise in separation distance is therefore necessary.

To maximise coupling, the geometry of the receiving phototransistor is arranged so as to expose an enlarged base area to the IR radiation from the emitting diode. This improves the coupling but results in increased base-collector capacitance and hence a reduction in speed.

As well as providing high d.c. voltage isolation, the separation of emitting diode and receiver results in very low capacitance coupling ($\simeq$1pF) which reduces the transmission of common-mode high-frequency noise. In digital applications, further immunity to the transmission of noise is given by the IR diode emission threshold which prevents emission until the applied forward voltage exceeds about 1V.

TABLE 1
Brief Data for Photocouplers

	Parameter		CNY22* CNY42	CNY23* CNY43	CNY44† CNY46	CNY47	CNY47A	CNY48	
	Isolation voltage input-to-output		4000pk (min)	2800pk (min)	1500pk (min)	2000rms (min)	2000rms (min)	1500rms (min)	V
I_C/I_F	Transfer ratio	min							%
	$I_F = 8mA, V_{CE} = 5V$		25	50	—	—	—	—	
	$I_F = 10mA, V_{CE} = 10V$		—	—	33	—	—	—	
	$I_F = 10mA, V_{CE} = 0{\cdot}4V$		—	—	—	20	40	—	
	$I_F = 10mA, V_{CE} = 1V$		—	—	—	—	—	600	
$V_{CE(sat)}$	Collector-emitter saturation voltage	max							V
	$I_F = 8mA, I_C = 2mA$		0·4	—	—	—	—	—	
	$I_F = 8mA, I_C = 4mA$		—	0·4	—	—	—	—	
	$I_F = 10mA, I_C = 3mA$		—	—	0·4	—	—	—	
	$I_F = 10mA, I_C = 2mA$		—	—	—	0·4	0·4	—	
	$I_F = 10mA, I_C = 60mA$		—	—	—	—	—	1·0	
V_{CEO} max	Max collector-emitter voltage		50	30	50	30	30	30	V
t_{on}	Turn-on time	typ	5·0	5·0	2·0	3·0	5·0	—	μs
t_{off}	Turn-off time	typ	5·0	5·0	2·0	3·0	5·0	—	μs
I_{CEO}	Dark current	max	100	100	100	100	100	100	nA

*CNY22 and CNY42 are electrically identical but CNY42 has no external base connection. This applies for CNY23 and CNY43 respectively
†CNY44 and CNY46 are electrically identical but differ in pin configuration

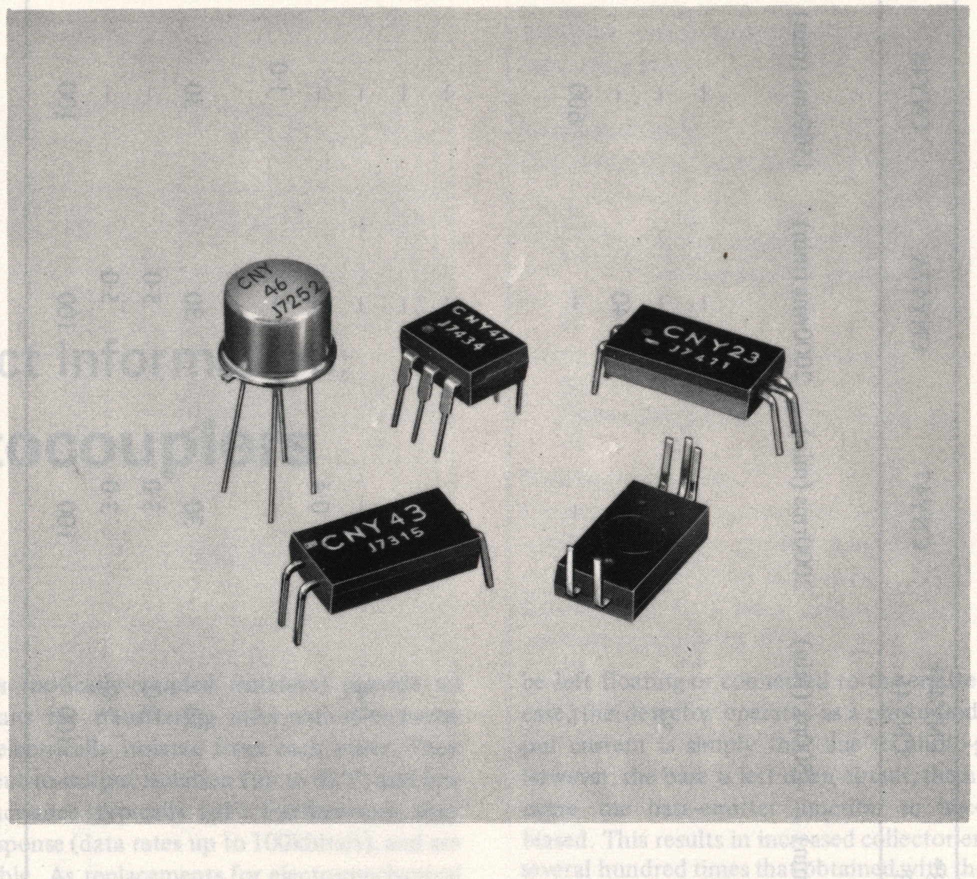

Fig.2 — Encapsulations used for the Mullard range of photocouplers

BRIEF DATA

Brief data for Mullard photocouplers is given in Table 1, and the encapsulations used are shown in Fig.2. Types CNY22, CNY23, CNY42, and CNY43 are plastic encapsulated as illustrated; types CNY44 and CNY46 are in TO-12 metal encapsulations; and CNY47, CNY47A, and CNY48 are in plastic 6-lead dual-in-line encapsulations. Full data on the devices in Table 1 is available on request.

APPLICATIONS

Photocouplers can be used in a wide range of applications including digital subsystem coupling, relay drive, line termination, overcurrent sensing, analog transmission, and motor control. Details of these and other applications are given in Ref.1 which is available on request.

REFERENCES

1. ‘Photocouplers’, TP1477, Mullard Limited, 1974.

Product Information:

High-grade long-life aluminium electrolytic capacitors

Mullard now provide a full range of high-grade long-life electrolytic capacitors particularly suited to switched-mode power supply filtering and to many other applications. These capacitors extend in range from 2·2 to 150 000μF at rated voltages between 4 and 63V.

The latest manufacturing techniques, together with improvements in the electrical parameters, give a high quality capacitor with exceptionally long life. The low effective series inductance of these capacitors meets the requirements of switched-mode power supply filters.

Ref.1 gives information concerning operating principles, structure, performance, quality and life for the Mullard capacitors in the 108, 071/072, and 106/107 series. The requirements of switched-mode power supply capacitors are also described in relation to these particular capacitors. The full range is given in Table 1.

MANUFACTURE

Details of manufacturing methods are given in Ref.1, and a typical capacitor from the 106/107 series is shown in Fig.1. The multiple internal connection visible in Fig.1 assists in the reduction of internal inductance and resistance to levels suitable for SMPS work.

APPLICATIONS IN SWITCHED-MODE POWER SUPPLIES

Since high-voltage fast-switching transistors have become available, switched-mode power supplies (SMPS) have come into common use. In the SMPS it is possible to utilise the rectified and smoothed mains directly in a switching circuit, thus eliminating the need for a bulky 50Hz transformer. The switching frequency is usually

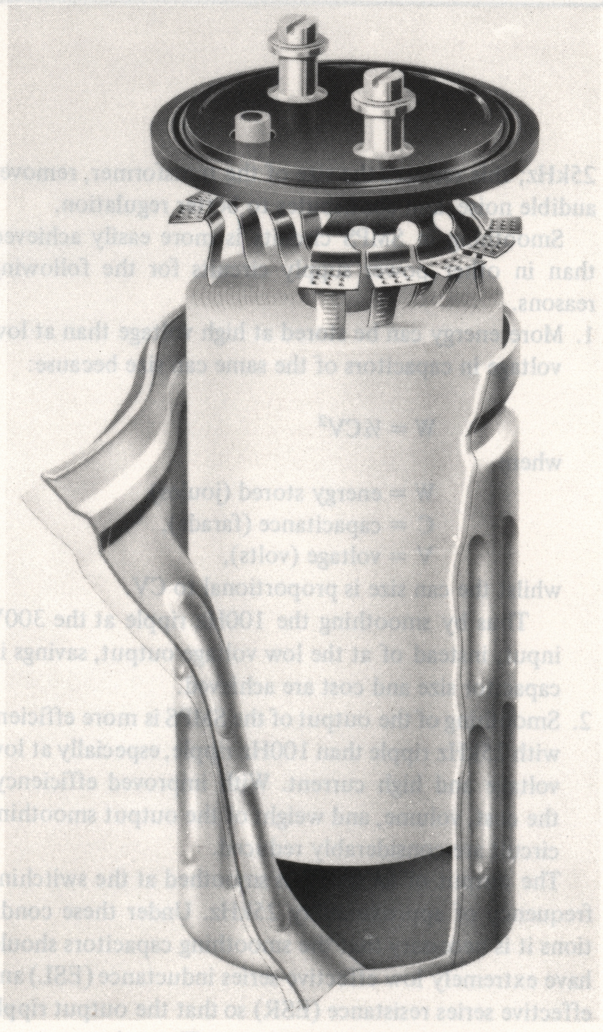

Fig.1 — Construction of 106/107 series capacitors

TABLE 1

Mullard Ranges of Electrolytic Capacitors

108 series						
Can size 5	Ø 8·3 × 22·5mm	6·3V	150μF	to	63V	10μF
to						
Can size 03	Ø 18·4 × 32·5mm	6·3V	2200μF	to	63V	150μF
071/072 series						
Can size 5	Ø 21·6 × 50·3mm	10V	4700μF	to	63V	680μF
Can size 6	Ø 25·6 × 50·3mm	6·3V	10 000μF	to	63V	1000μF
to						
Can size 10	Ø 40·8 × 81·3mm	6·3V	23 500μF×2	to	63V	2350μF×2
106/107 series						
Can size 11	Ø 36·5 × 83mm	6·3V	22 000μF	to	100V	1500μF
to						
Can size 16	Ø 66·5 × 115mm	6·3V	150 000μF	to	100V	10 000μF

25kHz; this reduces the size of the transformer, removes audible noise, and contributes to better regulation.

Smoothing in SMPS circuits is more easily achieved than in other power supply circuits for the following reasons.

1. More energy can be stored at high voltage than at low voltage in capacitors of the same can size because:

   $$W = \frac{1}{2}CV^2$$

   where

   W = energy stored (joules),
   C = capacitance (farads),
   V = voltage (volts),

   whilst the can size is proportional to CV.

   Thus by smoothing the 100Hz ripple at the 300V input, instead of at the low voltage output, savings in capacitor size and cost are achieved.
2. Smoothing of the output of the SMPS is more efficient with 25kHz ripple than 100Hz ripple, especially at low voltage and high current. With improved efficiency, the cost, volume, and weight of the output smoothing circuit are considerably reduced.

The output of an SMPS is smoothed at the switching frequency of approximately 25kHz. Under these conditions it is necessary that the smoothing capacitors should have extremely low effective series inductance (ESL) and effective series resistance (ESR) so that the output ripple voltage can be kept to a minimum. Thus when a capacitor is chosen for this application, the graph of impedance against frequency must be studied to ensure that the capacitor operates as a capacitor and not as an inductor.

Furthermore, smoothing capacitors for low-voltage high-current outputs (for example 5V, 100A) require low ESR to reduce the dissipation when the ripple current is high. If the ESR and ESL of a capacitor are low, load regulation is improved, particularly the response to step-changes of load current.

PUBLISHED DATA

The full document from which the above brief summary has been made is Ref.1. The complete operational characteristics of these capacitors is given in Refs.2 to 4.

REFERENCES

1. 'High-grade long-life aluminium electrolytic capacitors', Mullard New Product Information, Mullard Limited, TP1452, 1974.
2. 'Aluminium Electrolytic Capacitors – Large, high-grade, general purpose 071/072 Series', Mullard Published Data, Mullard Limited.
3. 'Aluminium Electrolytic Capacitors – Small, long-life, axial leads – insulated – 108 Series', Mullard Published Data, Mullard Limited.
4. 'Aluminium Electrolytic Capacitors – Large, long-life (computer grade) – 106/107 Series', Mullard Published Data, Mullard Limited.